LISBON
SCHOOL OF
ECONOMICS &
MANAGEMENT
UNIVERSIDADE DE LISBOA

MASTER´S DEGREE

MATHEMATICAL FINANCE

MASTER´S FINAL WORK

ACADEMIC INTERNSHIP REPORT

UK PENSION FUNDS: LIABILITY SENSITIVITY ANALYSIS

MIGUEL DUQUE SANTOS

OCTOBER 2019

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Abstract

In the United Kingdom, most employers offer their employees some type of occupational pension scheme. One of these types is a Defined Benefit pension plan, this is when an employer promises to pay a certain (defined) amount of pension benefit to the employee based on the final salary and years of service. So, in this type of occupational pension scheme, the employers bear all the risk, as they have to ensure the payment of the retirement benefits to the members when they fall due. The Actuaries are able to estimate the future payments and discount them to a current date. This present value of the future payments is called the liability and can be compared with the amount of assets to check there is enough money in the present to pay the promised future benefits. However, the liability is subject to variation over time because it is exposed to interest and inflation risk. Taking this into account, Mercer developed a sophisticated investment strategy called the Liability Benchmark Portfolio or LBP which is a low risk investment portfolio composed by zero coupon government bonds that will closely match the sensitivities of the liabilities to shifts in the inflation and interest rate. My task in the internship was to calculate these sensitivities of the liabilities that are required by the investment team to be able to build an LBP. Therefore, the risk will be reduced and we are closer to ensure that the members of the fund will receive their pension benefits, as promised.

Keywords: Liability Benchmark Portfolio; UK pensions; Interest and inflation risk; Defined Benefit pension scheme

Resumo

No Reino Unido, muitos empregadores oferecem aos seus empregados algum tipo de regime de pensões profissionais. Um destes tipos é o regime de pensões de benefício definido, isto é, quando um empregador promete pagar uma certa quantidade (definida) de benefícios de pensão ao empregado baseado no salário final e nos anos de serviço. Deste modo, neste tipo de regime de pensão profissional, o empregador suporta todo o risco, porque tem de garantir o pagamento dos benefícios de reforma aos membros quando eles vencem. Os atuários conseguem estimar os pagamentos futuros e descontá-los para a data atual. Este valor atual dos pagamentos futuros é chamado de responsabilidade e pode ser comparado com o montante de ativos para verificar se há dinheiro suficiente no presente para pagar os benefícios futuros prometidos. Contudo, a responsabilidade está sujeita a variações ao longo do tempo porque está exposta ao risco de juros e inflação. Tendo isto em conta, a Mercer desenvolveu uma estratégia de investimento sofisticada chamada "Liability Benchmark Portfolio" ou LBP que é uma carteira de investimentos de baixo risco composta por obrigações do governo de cupão zero que vão igualar aproximadamente as sensibilidades das responsabilidades a mudanças da taxa de inflação e de juro. A minha tarefa no estágio era calcular estas sensibilidades das responsabilidades, que são necessárias para que a equipa de investimentos consiga construir um LBP. Sendo assim, o risco vai ser reduzido e estamos mais perto de assegurar que os membros do fundo recebam os seus benefícios de pensão, como prometido.

Palavras-chave: Liability Benchmark Portfolio; Pensões do Reino Unido; Risco de juros e inflação; Regime de benefício definido

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List of Abbreviations

Abbreviation	Meaning
UK	United Kingdom
LBP	Liability Benchmark Portfolio
DB	Defined Benefit
WAS	Wealth Analytical Services
SERPS	State Earnings-Related Pension Scheme
S2P	State Second Pension
RACs	Retirement Annuity Contracts
SIPP	Self-Invested Personal Pension
DC	Defined contribution
SSAS	Small Self-Administered Schemes
PV	Present Value
FPS	Final Pensionable Salary
FAE	Final Average Earnings
BAE	Best Average Earnings
CARE	Career Averaged Revalued Earnings
TPR	The Pension Regulator
OPRA	Occupational Pensions Regulatory Authority
PPF	Pension Protection Fund
TPAS	The Pensions Advisory Service
DWP	Department of Work and Pensions
HMRC	Her Majesty's Revenue and Customs
GMP	Guaranteed Minimum Pension
NAE	National Average Earnings
RPI	Retail Prices Index
CPI	Consumer Prices Index
TP	Technical Provision
SFO	Statutory Funding Objective
IAS19	International Accounting Standard 19
FRS102	Financial Reporting Standard 102
CMI	Continuous Mortality Investigation
LPI	Limited Price Index
IRP	Inflation Risk Premium
JY	Jarrow Yildrum
AWE	Average Weekly Earnings
LDI	Liability Driven Investment

1. Introduction

This report is the Master final work for the Mathematical Finance Master´s degree in ISEG, based on a four months internship from 5th March to 4th July 2018 in Mercer (consulting firm).

Mercer is a subsidiary of the global professional services firm Marsh & McLennan Companies, Inc with its headquarters in New York and is present in 44 countries. It is divided in three lines of business: Health, Wealth and Career. There is an additional area, the Wealth Analytical Services, which is where this internship took place. Mercer Portugal started in 1993 and has more than 480 employees in two offices, the main office in Lisbon (were the internship took place) and another office in Oporto.

On this internship, I work with defined benefit (DB) pension schemes, an important type of pensions in the United Kingdom (UK) since most companies offered a DB pension scheme to their employees. A defined benefit pension scheme, also known as final salary, is a type of pension where the employer makes contributions into a trust account and must ensure there is enough money in the trust account to pay the employee a pension income. This pension income is determined by a formula, often based on the earnings, years of service and accrual rate of each member. The contributions made by the employer vary and are calculated in order to meet the benefits assumed in the scheme, so the risk is bearded by the employer. Although the number of DB pension schemes has been decreasing over time, mainly due to the risks and costs associated with this type of pension scheme, there are still several DB pension schemes which need to be monitored in order to guarantee the payment of all the benefits due to all the members of the scheme. In order to meet all these liabilities my job during the internship was to do an analysis on the sensitivities of the scheme´s liabilities i.e. calculate the increase or decrease of the liabilities from changes in the market expectation on future levels of inflation and interest rates. The purpose of this analysis is for the investment teams to be able to hedge the liabilities and therefore create a portfolio that will match the pension schemes sensitivity to changes in the inflation and interest rate. This is an important step to ensure that the benefits promised to each employee are meet on the time due.

This report is divided in six chapters, first the introduction, then in the second chapter is a description on the company where the internship took place (Mercer). In the third chapter we will learn more about pension in the United Kingdom to have a general idea on the types of pensions available. The fourth chapter will look with more detail at the defined benefit occupational pension schemes: the main parties involved in this schemes and the actuarial valuation methods and assumptions. There is a description of the internship activities in the fifth chapter, where we will have a closer look at liabilities, its sensitivity analysis including the process and all the parameters. The sixth chapter will show the conclusion of this internship report and the limitations of the LBP approach.

2. Mercer

This report is based on an internship carried out in Mercer Portugal, so in this chapter we will learn more about this company. It will present a brief history of the company, both internationally and nationally. We will explore its main goals and structure and strategy of the organization.

2.1 History

Mercer began in 1937 in Canada as a provider of actuarial and benefits consulting services by the name "William M. Mercer, Ltd" founded by William Manson Mercer. In 1959, Marsh & McLennan acquired this company, which became a wholly owned subsidiary of Marsh & McLennan Companies, Inc and merged into the company´s employee benefits department with the new name "William M. Mercer" and headquartered in New York. Afterwards, it was renamed "Mercer Human Resource Consulting" in 2002.[1] It is based in 44 countries with more than 23.000 employees. In Portugal, Mercer started in 1993 with an office in Lisbon and then a second smaller office in Oporto. In 2017, Mercer Portugal acquired Jason Associates, a talent management consulting company. It currently has 480 employees.[2]

2.2 Mission, purpose and values

The main goal at Mercer is to improve people´s lives by their ideas and actions and making a positive difference in more than 110 million lives around the world. Their purpose is to contribute to improving the tomorrow through the actions they promote today and that is why Mercer´s slogan is "Make Tomorrow, Today".[3] This complemented with Mercer´s mission of helping their clients to improve the career, wealth and health of their people is what unites all the employees to the same goal: "The Greater Good". With this goal in mind, Mercer develop a series of values called the Mercer PRIIDE.[4]

Passion – "to win and be the best at what we do";

Respect – "for diversity: listening to and collaborating with others";

Integrity – "in everything we do: knowing what is right and acting responsibly";

Innovation – "that anticipates our client needs and reshapes the marketplace";

Dedication – "to serving our clients with unparalleled quality and proven success";

[1] https://en.wikipedia.org/wiki/Mercer_(consulting_firm)
[2] https://pt.linkedin.com/company/mercer-portugal
[3] https://www.mercer.com/about-mercer.html
[4] https://www.mercer.com/mercer-careers/why-we-come-to-work.html

Empowerment – “to act like business owners and be accountable for our decisions”.

These values represent the bedrock of Mercer´s four strategy imperatives: People, Clients, Company and Shareholders.

2.3 Mercer House

Figure 1: Mercer House Source: Author

2.4 Organizational Structure

As a world leader consulting company, Mercer is structured by three main business areas: Health, Wealth and Careers. Mercer´s Health department advices their clients on benefits management, finds benefits solutions for small and medium-sized businesses as well as privates, deliver diagnosis, design and implementation of benefit policies. The Wealth division implements strategy definition, management structure, monitoring of investments and operational risk analysis of managers and banks. This department also provides defined benefit pension plans, defined contribution and hybrids. The third business area, Career, assists companies on management of skills and careers, remuneration policies and talent assessment. It also makes market studies on several areas like compensation, benefits and industry.

Furthermore, Mercer has an excellence´s centre, the Lisbon Wealth Analytical Services (WAS), which operates in the Wealth business area and works for 14 countries in more than 40 different services [Mercer (2019g)]. In 2016 alone, this division had an impact on more than 2 million lives around the world (in Portugal, United Kingdom, Germany, Netherlands, Ireland and others). The Lisbon WAS is divided in two areas: Actuarial

Services and Financial & Administration Services. The first area works with post-retirement benefits for both individuals and companies pension plans (individual actuarial calculations and actuarial valuations, respectively). The main responsibilities are data analysis and financial risk valuation. The Financial & Administration Services has three main operating areas. The Performance Monitoring team which has as main goal the delivery of performance monitoring reports for pension funds in several European countries, which includes value in the portfolio of fund managers, investment analysis and strategies. The Financial Monitoring area provides several services for the United Kingdom, Ireland and Brazil and is responsible for the benefit calculation of each member of the pension fund and the validation of existent data in the system. The third area is the De-risking team, which was where I had the opportunity to work during the internship. It is a recent team in constant expansion, which enables a continuous learning process, almost daily, not only for me as an intern, but also for the other team members. This team provides many services to the United Kingdom, mainly monitoring and modelling the financial level of pension fund and providing analysis on pension fund associated risk, as for example the inflation, interest rate and longevity.

3. UK Pension Funds

Throughout this internship, the tasks performed were around UK pension funds, more specifically defined benefit (DB) pension schemes. The main goal of this chapter is to provide a general understanding on how the pension work and what type of pensions there are in the United Kingdom. There are three main types of pensions in the UK: the State pensions, personal pensions and occupational pensions, which this report will address more deeply, as the activities performed in the internship were related to this type of pension.

3.1 State Pension

The main goals of a pension are to grant a decent life and avoid poverty in old age. The elderly are no longer capable of performing paid work, so the State should ensure a certain income proportional to the earnings of the individual while working. The first UK pension system was introduced in 1908 by the Old-Age Pension Act 1908. This was a non-contributory pension system bore by the working population. Under this act, people would receive 5 shillings per week and in order to be eligible they should be over 70 years old, earn less than 31 pounds and 10 shillings per year, live in the UK for at least 20 years, worked their entire lifetime and even had to pass a “character test”.[5] Then came the Widows', Orphans' and Old Age Contributory Pensions Act 1925, the first contributory state pension system funded by the employees and employers. After the Second World War, a social security system (the Basic State Pension) was established by

[5] https://en.wikipedia.org/wiki/Old-Age_Pensions_Act_1908

the National Insurance Act 1946 and introduced in 1948. Under this legislation, the working population must pay a contribution every week (called the National Insurance contribution) and were entitled to several benefits, for example unemployment and sickness benefit and more important a pension when they reach retirement [Bozio, A., Crawford, R. and Tetlow, G. (2010)]. However, the contributions made by the individual while working are not linked to his/her own future pension, as this contribution are used to finance the present pension benefits to the retired. The men born before 6th April 1951 and the women born before 6th April 1953 are entitle to the basic State Pension, whereas if they were born after those dates, they can claim the new State Pension.[6] The initial pension amount is based on the individual´s National Insurance contribution history and not on their earnings. For an individual to be eligible to a full pension, it is required at least 30 qualifying years of National Insurance contribution in the basic State Pension and 35 in the new State Pension [The Pensions Advisory Service (2019b)]. When people don´t have those qualifying years required, they will receive a lower pension amount based on their National Insurance contributions. The full pension amount is set by the Government annually in April and it is currently £129.20 and £168.60 per week (between 8 April 2019 and 5 April 2020) for the basic and new State Pension, respectively [The Pensions Advisory Service (2019a)]. In addition to the Basic State Pension, there is the Additional State Pension which provides a supplementary pension income to the Basic State Pension and was also replaced after 6th April 2016 by the new State Pension. The current additional pension state scheme is the State Second Pension (S2P) which was introduced on 6th April 2002. There have been two different schemes prior to the S2P. The first scheme was the Graduated Retirement Benefit which was presented on 6th April 1961. It was replaced on 6th April 1978 by the State Earnings-Related Pension Scheme (SERPS) which preceded the current scheme (S2P). The Additional State Pension is not mandatory, so individuals can contract out, which means that they can choose not to participate in this component of the State Pension. However, they are only able to contract out if they have another additional pension as a personal pension or an occupational pension scheme [GOV.UK (2019)].[7]

3.2 Personal Pension

The personal pension plans are a good choice for individuals who are self-employer or when companies don´t have a pension scheme for their employees. Also, these plans are open to individuals who are unemployed and if they are employed their employer can make contributions too. The personal pension plans were introduced on 1st July 1988 and replaced the Retirement Annuity Contracts (RACs). These individual contracts were available to those in self-employment or to those in employment which didn´t have a company pension plan. The purpose of the RACs is to build a retirement benefit for those individuals by buying an annuity from a pension provider, generally an insurance company. After 6th April 2006, when the HM Revenue & Customs approved a new set of rules, the RACs became very similar to the personal pension plans and lost

[6] https://en.wikipedia.org/wiki/State_Pension_(United_Kingdom)
[7] https://en.wikipedia.org/wiki/State_Second_Pension

almost all their special features.[8] The personal pension plans are a type of defined contribution arrangement where individuals make contributions to a chosen provider, usually an insurance company, but also by independent providers as for example a banks, investment organisations, some retailers or building societies. These plans are available to any individual who is under 75 years old and can retire at any age after 55 (depending on the plan restrictions). They can usually take up to 25% of their pension pot as a tax-free lump sum and can use the rest of the pot to buy an annuity from an insurance company [Mercer (2019c)]. There are several types of personal pension schemes. Some examples are the Stakeholder pension scheme, the Group personal pensions and the Self-Invested Personal Pension (SIPP). The Stakeholder pension scheme was introduced by the Welfare Reform and Pensions Act 1999 on 6th April 2001 and it is a type of defined contribution scheme that must meet some rules set by the Government, which include flexible and low minimum contributions, a default investment fund, limited charges and charge-free transfers.[9] Even though it is a personal pension scheme, the employers can offer it to the employees and in some situations, they are required to do so [Money Advice Service (2019a)]. Another type of personal pension that the employers can provide to their employees is the Group personal pensions, however it is still an agreement between the employee and the pension provider. As this is a pension plan with a group of employees, the employer can negotiate a discount on the pension provision costs, which might result in lower charges when compared with an individual personal pension.[10] If individuals prefer to have more control over the investment decisions, they can choose a Self-Invested Personal Pension (SIPP). The SIPP is similar to other personal pensions but gives individuals the freedom and flexibility to manage their investments or to choose an investment manager to make the investment for them.[11] Still, this type of personal pension is more recommended to individuals with experience in financial market [Money Advice Service (2019b)].

3.3 Occupational Pension

Company Pension schemes, more commonly known as Occupational pension schemes, are pension schemes that the employers set up to provide their employees with pension benefits, usually by arranging a pension trust fund managed by trustees or even hand over to an insurance company. These plans can be non-contributory, when the employers are the only ones that can make contributions to the fund and the employees are not allowed to, or they can be contributory, when the employees can make their own contributions to the fund, in addition to the contributions of the employers. The types of occupational pension schemes are the Defined contribution (DC) and Defined benefit (DB) schemes which will be explored in more detail in this section. There is also a third type called the hybrid schemes which are a combination of both defined contribution and defined benefit schemes´ features.

[8] https://www.pensionsadvisoryservice.org.uk/about-pensions/pensions-basics/contract-based-schemes
[9] https://en.wikipedia.org/wiki/Stakeholder_pension_scheme
[10] https://en.wikipedia.org/wiki/Pensions_in_the_United_Kingdom
[11] https://en.wikipedia.org/wiki/Self-Invested_Personal_Pension

3.3.1 Defined contribution schemes

Nowadays, as most defined benefits schemes are closed to new members due to the costs and risks associated to the employer, the majority of employers are offering a DC scheme, also known as money purchase schemes, to their employees, thus decreasing their risk exposure. Under this type of pension scheme, the employee and employer make a fixed contribution defined by the plan (usually a proportion of the employee´s salary) to an account usually known as pot. Then the employees can choose different investment options with different risk levels, depending on their risk tolerance, therefore the risk is supported by the employees. The employer only assumes legal risks whereas the employee bears most of the risks, including inflation, longevity and investment risk [Mercer (2019c)]. The following table shows the risk distribution in a defined contribution scheme:

Type of Risk	Who bears the risk
Investment	Employee
Inflation	Employee
Longevity	Employee
Market timing	Employee
Employer insolvency	DC schemes are always fully funded
Salary replacement risk	Employee
Legal risk	Employer

Table 1: Risk distribution in DC scheme, Source: Broadbent, Palumbo and Woodman (2006)

The pension benefits will depend on the contributions made by both the employer and employee, the investment choice and how this investment performed over time. This causes the amount of the pot that the employee will receive on retirement to be difficult to predict thus no actuaries are required, the scheme is always fully funded and the contributions made to the pot are the only certainty in this type of pension. The diverse investment options available for the member to invest are chosen by the scheme trustees, typically with the help of professional advisers. These investment options range from low risk (gilts and bonds) to high risk options (equity funds). At retirement, the individuals will use the pot to buy a pension benefit, known as an annuity, and they can choose the kind of benefits the pension includes, for example death benefits, which will affect the amount of pension the individuals will receive. A particular type of a DC scheme is the Small Self-Administered Schemes (SSAS). This plan is usually for a small group of members, for example the company´s directors and the senior partners, usually with a group up to 11 members and one important distinction of a SSAS is that those members should all be trustees. This type of scheme allows members to choose where to invest the contributions and since it has many exceptions from the pension legislation that is applied to other schemes, the range of investment choices are wider and has less administrative requirements [Mercer (2019c)].

3.3.2 Defined benefit schemes

Although most defined benefit (DB) schemes are close to new entrance, there are still many schemes in operation (over 6,000 in 2015).[12]

The DB schemes are set up under a trust, supervise by trustees, so it is independent to the employing firm. This type of schemes, also known as final salary schemes, promise to pay a pension income to their members based on a benefit formula and employers have to guarantee that the amount of money in the trust account is sufficient to meet all the liabilities. This pension often includes additional benefits such as death benefits to the spouse, increases in payment and disability benefits.

The employer and employee make contributions to this trust account which may change in case the contributions don´t meet the benefits the plan assumes. Each employee doesn´t have its own pot, like in the defined contribution plans, instead it is all mixed together in the same trust account due to the fact that pension income is not explicitly determined by the contribution but by a formula (Equation 1). For this reason, an actuary is required in order to forecast the amount of pension the members will get upon retirement and calculate its present value (PV) to estimate the funding level. If the scheme is underfunded (when there are less assets than liabilities), the employer will need to increase the contributions to the trust account. Whereas if it is overfunded (when there are more assets than liabilities), the employer can decrease the contributions [Mercer (2019c)]. As a result, the employer bears most of the risk associated with DB schemes, although the employee also bears some risk such as the inflation risk and in case of insolvency of the company. The table below shows the risk distribution in a defined benefit scheme:

Type of Risk	Who bears the risk
Investment	Employer
Inflation	Employer/Employee
Longevity	Employer
Market timing	Employer
Employer insolvency	Employee/Taxpayers
Salary replacement risk	Employer

Table 2: Risk distribution in DB scheme, Source: Broadbent, J., Palumbo, M. and Woodman, E. (2006)

The most common benefit formula used to calculate the annual pension income is based on the following factors:

- Pensionable service – the period of service allowed in the calculation of the scheme benefits, depending on the plan´s rules;
- Final Pensionable Salary (FPS) – based on the employee final salaries (depends on the scheme's rules);
- Accrual rate – the percentage of income the employee will receive (usually 1/60th or 1/80th).

[12] https://en.wikipedia.org/wiki/Pensions_in_the_United_Kingdom#Defined_benefit/final_salary_schemes

Mathematically, the formula can be presented as:

$$Pension = Pensionable\ service * FPS * Accrual\ rate. \quad (1)$$

As said above, there are different benefit formulas that can be provided with different rules and different definitions to each factor. The most common are:

- Final Average Earnings (FAE) – average of the employee final years of salary (usually the last three or five years, when the salary is higher);
- Best Average Earnings (BAE) – average of the highest salaries from a certain number of years;
- Flat Amount – based on a fixed amount for each year of pensionable service.

To avoid the costs and risks associated with DB schemes, there are more and more employers offering DC schemes, where a weak investment return will result in a smaller pot for the employee. However, if the employers want to provide better retirement benefits to their employees another alternative is the Career Averaged Revalued Earnings (CARE). It is similar to a DB plan but is less expensive for the employer. A CARE scheme provides the employee a pension income based on the average of all its salaries adjusted for inflation over the pensionable service period. It usually provides a lower pension income than the final salary pension [The Pensions Advisory Service (2019d)]. The employees prefer DB over DC schemes, because it provides them a certain amount of pension benefits at the retirement age without assuming any investment risk. The downside of this type of plan is that it has a great costs for the employer who needs to increase the contribution in case the investments underperform and the fund cannot meet the liabilities. The employers have had to pay a vast amount of additional contribution in recent years.

While there are still operational DB schemes, even when closed to new entrance, there is the need to hedge the liabilities against the risks associated, in the case of this report, changes in the inflation and interest rates. Further on, we will have a closer look on how to calculate the changes on liabilities against movements in the expected future level of inflation and interest rates, an important step so that the investment teams can built a portfolio which will closely match the sensitivities of a pension fund to changes in these factors [Mercer (2019a)].

3.3.3 Hybrid schemes

Another kind of occupational pension is the hybrid scheme which is a mix of characteristics from both DC and DB plans. Unlike the DC and DB schemes where the employee and employer, respectively, bear the risk, in a hybrid scheme they can share the risk between them. The most common type of hybrid scheme is the cash balance plan, which is very similar to a DC schemes, however for legal purposes it works as a DB plan. The employer makes contributions to an individual pot of each employee and at retirement they will receive a lump sum to buy an annuity like in a traditional DC plan. The difference is that this pot is not directly related to how the investments perform and

the employer will offer some guarantees if the investment returns are less than the minimum level, thus reducing the investment risk faced by the workers [The Pensions Board (2007)].

Other types of hybrid plans are described in the following table [The Pensions Board (2007)]:

Types of hybrid plans	Description
Underpin arrangements	The pension benefit the employee will receive is based on the calculation that provides the best benefit. It can be predominantly DC or DB scheme depending on the plan.
Final salary lump sum schemes	Similar to a DB scheme, but instead of a pension at retirement, employees will receive a lump sum. This amount can be forecast (proportion of final salary), but the annuity the employee can buy is difficult to predict (depends on market conditions at the time). This will remove the longevity risk from the scheme.
Fixed benefit/benefit unit schemes	Similar to a DB scheme, but not linked to earnings. Every year the employee accrues a fixed amount of annual pension which is based on the contribution made and the remaining period to retirement. The employee will receive at retirement the total amount of pension set up every year.
Self-annuitising DC schemes	Similar to a DC scheme, but at retirement the scheme pays a pension income to the employee, which is not based on market conditions, but according to the rules established by the scheme. The benefits are easier to forecast but will depend on how the investments return.
Combination hybrids	The employee will accumulate two types of benefits at the same time, usually for the first fraction of income a DB and then a DC for any earning exceeding that amount.

Table 3: Types of hybrid schemes, Source: Author

Amongst the range of hybrid plans there are more complex schemes, for example a combination of several hybrid schemes, like a self-annuitising cash balance scheme.

The hybrid scheme is a good alternative to employers that want to reduce their risk exposure, because it divides the risk between employer and the employee by combining the advantages of both DB and DC plans and avoiding partially their disadvantages.

4. Defined Benefit pension schemes

Even though in the previous chapter there is an introduction on DB schemes and its main features, since the activities of the internship were around this type of pension, this chapter will deepen the knowledge on DB schemes by looking at the institutions and people involved as well as the methodologies and assumptions of an actuarial valuation, which is an important step because not only it estimates the liabilities, but also estimates the expected future cashflows required to analyse the sensitivity of the liabilities to changes in the interest and inflation rate.

4.1 Responsibilities and roles

This section describes the key parties who are involved with the management and administration of a DB scheme both the people and the institutions [Mercer (2019c)].

4.1.1 People

- **Employee/member** – individual which is employed by the employer under an employment contract and becomes a participant when it starts to participate in the pension plan. The participant doesn´t need to be working in the company, it could be a former worker which is entitled to the pension benefits. In case of death of the participant, the pension benefits will be received by the beneficiary.
- **Spouse** – person who is legally married to the member of a pension fund. The spouse is usually the beneficiary of the participant. It is considered a surviving spouse the individual who is married to the member at the time of death. When the spouse has been married to the member for a short time the scheme might exclude the surviving spouse, depending on its rules.
- **Employer** – individual who provides a pension scheme to their employees and sponsors it and is required to fund the scheme and make the necessary contributions.
- **Administrator** – person who manages the daily tasks and the strategy choices of a pension scheme and administers it. The administrator has to inform the employers of their responsibilities and rights as well as provide them the necessary documents and information. The administrator is in charge of paying the pension benefits to the pensioners and beneficiaries as it is the only who can authorize payments from the trust. Another responsibility is making sure the contributions are being made to the fund and guarantee suitable asset allocation decisions.
- **Trustee** – individual or company that is in charge of managing the trust and ensures the pension plan operates correctly under the regulation and specific rules of the scheme. By law, most DB schemes in the UK are required to be arranged as a trust. The trustee acts separately from the employer and ensures the contributions made by the employer are enough to cover the future benefits. The trustee should always be honest, impartial, prudent and act in the best interest of the beneficiaries and members of the pension plan. Another

responsibility is to hold the assets in the trust and supervise the investment portfolio and by law must assign advisers, like actuaries, investment managers and auditors [Marcaillou, P. (2016)].

- **Actuary** – professional who advises the trustees and employers on all aspects of the funding of the pension scheme. The actuaries provide a triennial actuarial valuation report, which sets a value on the liabilities of the scheme and will be compared with the amount of assets, to enable an arrangement between the trustee and employer on the amount of present and future contributions that should be made to meet the liabilities, after accounting for any deficit or surplus. They should also advise on all important decisions and implication related to the scheme funding as well as approve the calculation of technical provision and the schedule of contributions. Another responsibility is estimating the transfers out and the member benefits on transfers in of the pension plan.
- **Investment manager** – individual or company chosen by the trustees to advise them on all the investments of the pension fund.
- **Auditor** – most pension schemes must have an auditor chosen by the trustee, which can be an individual or company, to provide a statement about the contribution made to the scheme and audit the accounts of the scheme.
- **Lawyer** – individual who advises the trustee on legal issues that might occur on the pension scheme.

4.1.2 Institutions

- **The Pension Regulator (TPR)** – institution that regulates the workplace pension schemes. It ensures the employers provide a pension plan to their employees and make the required contribution. On 6th April 2005 it replaced the Occupational Pensions Regulatory Authority (OPRA) and was established under the Pension Act 2004. Its main goals are: reduce the risk of resorting to the Pension Protection Fund (PPF); develop a better understanding of a good management of a workplace pension plan; protect the benefits of members; ensure the maximum compliance by the employers on their duties. It collects information annually on pension schemes to identify those that represent a major risk to the benefits of the members and helps these schemes to reduce the risk by increasing the liabilities and assets management [Marcaillou, P. (2016)].
- **Pension Protection Fund (PPF)** – introduced by the government on 6th April 2005 under the Pension Act 2004 to protect the benefits of member. In case of insolvency, it compensates the eligible members of defined benefits pension schemes, which promotes the confidence in pension schemes. It is funded by annual levies from all DB schemes. It is also responsible for the Fraud Compensation Fund, which protects and compensates members who lose their retirement benefits in case of fraud.[13]
- **The Pensions Advisory Service (TPAS)** – independent non-profitable institution which helps people with problems related to their pension and provides free

[13] https://en.wikipedia.org/wiki/Pension_Protection_Fund

information and guidance on all types of pension (state, personal and occupational pensions). The TPAS also provides insight to the industry and government in order to support the development and improvement of pension policies. It is run by a group of experience volunteers and is grant-aided by the Department for Work and Pensions [The Pensions Advisory Service (2019e)].

- **Department of Work and Pensions (DWP)** – a department of the UK Government established on 8th June 2001 which is in control of the pension and welfare policy. It is divided in four operational institutions: Jobcentre Plus; Disability and Carers Service; Child Maintenance Group; Pension Service which is responsible for the calculation and payment of state benefits. The administrators of pension schemes are in constant contact with this department to settle the Guaranteed Minimum Pension (GMP) payable to the members who retire, die or transfer out.[14]
- **Her Majesty's Revenue and Customs (HMRC)** – non-ministerial department of the United Kingdom Government[15] formed on 18th April 2005 by the merger of the Her Majesty's Customs and Excise and Inland Revenue. It has many responsibilities such as collecting taxes, the payment of state support and manage other regulatory norms like the national minimum wage. For pension schemes it established the detailed regulations which includes: the payments that will get tax exemptions and how the payments are taxed; the upper limits of benefits and contributions.

4.2 Actuarial Valuation

An actuarial valuation is very important on DB schemes and must be provided at least every 3 years. It estimates the present value of future benefit payments (liabilities) which is then compared with the current market value of assets to schedule the contributions and to find the funding position of the scheme. It can be indicated by the funding level, which is the ratio between the assets and liabilities of the scheme or by subtracting the assets to the liabilities thus having a deficit or surplus. If the scheme is not fully funded the trustee must provide a recovery plan, which will establish the amount of money that should be paid into the fund, within 15 months of the valuation date and it should be agreed with the employer in most cases. There are several valuations methodologies that usually generate different funding positions and the employer and trustees have to choose the approach they wish to achieve depending on their strategy and objective. These methodologies will be explained in more detail on the next section [Mercer (2018c)].

There usually are three types of member in a pension schemes which the actuary needs to consider [Marcaillou, P. (2016)]:

- Active member – employee that is currently working in the company and is still contributing to the scheme.

[14] https://en.wikipedia.org/wiki/Department_for_Work_and_Pensions
[15] https://en.wikipedia.org/wiki/HM_Revenue_and_Customs

- Deferred member – former employee which is no longer contributing to the scheme and hasn´t reached the retirement age, so doesn´t receive benefits yet.
- Pensioner member – member who is already retired and is receiving retirement benefits.

Most DB schemes don´t have active members since most of them are closed to new entrance and the new employees should be on other type of pension scheme.

The set of cashflows the actuary estimates are usually combined in tranches with the same increases and not by member. Each status receives a different type of indexation before payment which has to be considered when estimating the future cashflow payments. The various types of indexations that the benefits of members are subject to are illustrated in Appendix 1.

Although in Appendix 1 shows four different indexation periods, in practice to represent the benefits of members it is usually required a maximum of three different types of indexation. This is due to the fact that one or more of these periods are not applicable or merged together, depending on the members´ status. Below there is a table that summarizes the different types of indexation for each status:

	Period 0	**Period 1**	**Period 2**	**Period 3**
Active members	Not applicable	Future revaluations before decrement (salary increases), specified by length of t_1.	Future revaluations in the period from decrement to start of payment (deferred revaluations). Applicable over period specified by t_2.	Pension increases, applicable over period t_3
Deferred members	Historic revaluations since date of leaving to now, specified by t_h.	Future revaluations from now to start of payment, specified by length of t_1	Not applicable: period t_2 should be the same as t_1.	Pension increases, applicable over period t_3
	These two periods are merged together for increases subject to caps/floor that apply cumulatively over the period since date of leaving to start of payment ($t_1 + t_h$)			
Pensioners	Not applicable	Future GMP revaluations from now to start of payment, specified by length of t_1	Not applicable: period t_2 should be the same as t_1.	Pension increases, applicable over period t_3

Table 4: Indexation periods by member, Source: Mercer (2018d)

The scheme´s rules define the type of revaluation and pension increase the benefits will receive, however there are minimum increases that the pension schemes have to provide which were introduced by several legislations, for example the Pension Act 1993, 1995 and 2004. Although the pension scheme can offer greater increases than the ones established by the legislation. The DB schemes for members who contract-out of the State Earnings-Related Pension Scheme (SERPS), the previous Additional State Pension, between 6th April 1978 and 6th April 1997, are required to receive a minimum amount of pension known as Guaranteed Minimum Pension (GMP). Within these dates there is a distinction on how the GMP is calculated between the period prior to 5th April 1988 and after that date due to changes in the rules [Thurley, D. (2018)]. There are different statutory minimum requirements for revaluation of deferred pensions and pensions in payment. For deferred pensions that accrued before 6th April 1997 there are three options for revaluation of GMP [Old Mutual Wealth (2019)]:

- **Fixed rate** – a nominal rate not linked to inflation which depends on the date of leaving.
- **Section 148 orders** – the S148 orders, previously known as Section 21 orders, increases in line with the National Average Earnings (NAE) index.
- **Limited Revaluation** – in line with S148 increases but limited to 5% per annum (p.a.) for leavers before 6th April 1997.

Deferred pension benefits also revaluate in excess to GMP, depending on the date of leaving. Before 1st January 1986 there is no statutory revaluation requirement, called Non-Revaluing Excess. After that date and until 1st January 1991, pensions revaluate in line with inflation prices, Retail Prices Index (RPI) or Consumer Prices Index (CPI), or 5% p.a. whichever is lower, called Revaluing Excess. Between 1st January 1991 and 5th April 2009 pensions also revaluate in line with inflation prices (RPI or CPI) or 5% p.a. whichever is lower. After 6th April 2009 under the Pensions Act 2008 pensions revaluate in line with inflation prices (RPI or CPI) or 2.5% per annum [Barnett Waddingham (2019)]. These three last increases are commonly known as Section 52a orders or also Section 84 orders. Under the Pension Act 2011, on 6th April 2011 the basis of the statutory minimum requirement switches from RPI to CPI. The pension revaluation in deferment describe above is illustrated in the following figure:

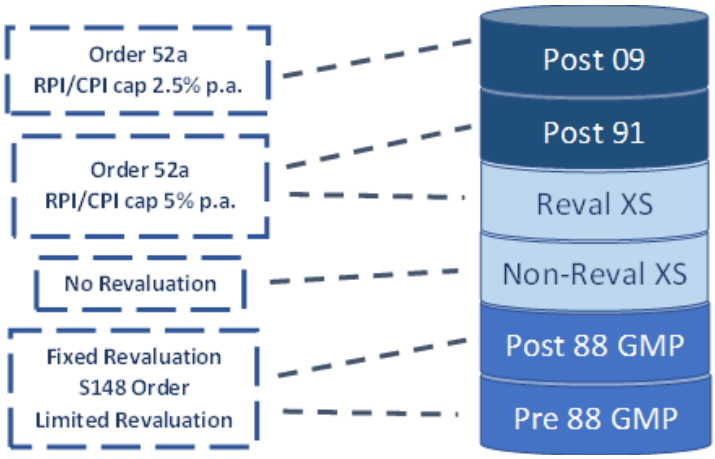

Figure 2: Pension revaluation in deferment Source: Mercer (2018c)

The figure below shows three examples of how pensions revaluate in excess to the GMP for different leaving dates:

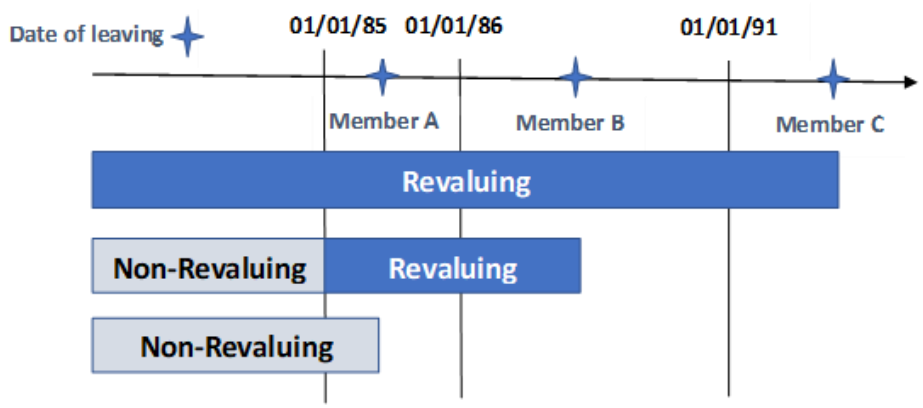

Figure 3: How pensions revaluate Source: Mercer (2018c).

Member C leaves after 1st January 1991 so all benefits will revaluate in excess to GMP. If the member leaves before 1st January 1986, like member A, the pension is not subject to revaluation. In the case of member B who leaves between those dates, the pension will revaluate in excess to GMP after 1st January 1985, but prior to that it will not revaluate. All of these revaluations are the statutory minimum, some schemes can provide more favourable benefits for members and so revaluating all pension for any leaving date. If the scheme provides the statutory minimum requirements, it is expected for members who left before 1st January 1991 to have a component of non-revaluation pension.

The DB schemes are also required by legislation to provide minimum increases to pension in payment. The GMP for pension increases between 6th April 1988 and 5th April 1997 is in line with inflation prices cap at 3% p.a. and before that date doesn´t have a statutory minimum requirement so it is usually a fixed 0% rate. The Revaluing excess and Non-Revaluing excess (before 5th April 1997) are specific to each scheme and don´t have a mandatory increase. Under the Pension Act 1995 between 6th April 1997 and 5th April 2005 the pension in payment increase in line with inflation prices cap at 5% per annum [Expert Pensions (2019)]. This cap was reduced to 2.5% for pension earned after 6th April 2005 under the Pension Act 2004. Below there is a figure that illustrate the above:

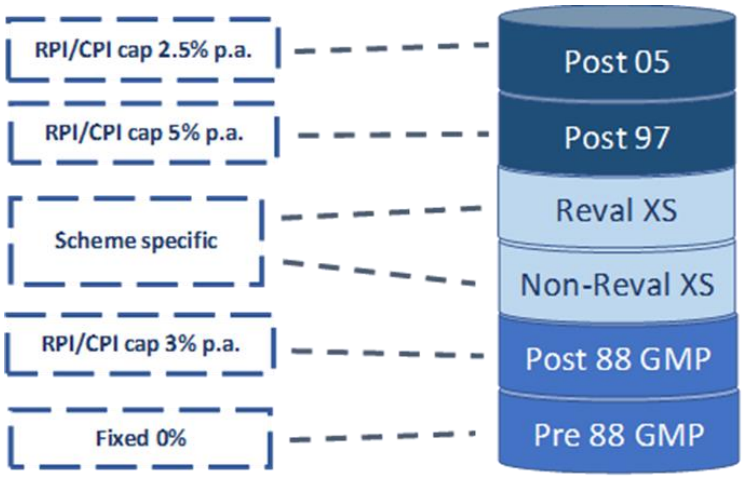

Figure 4: Pension in payment Source: Mercer (2018c)

It is very important to understand the way the pension revaluates and increases when modelling the calculations for the sensitivities of the liabilities. This is explained in more detail in the next section.

4.2.1 Valuation methodologies

There are five types of valuation methodologies carried out by the actuaries which provide different funding ratios [The Pensions Regulator (2018)]:

- **Technical Provision (TP)** – it is used to measure the liabilities of the scheme and check if the assets cover the benefits promised. This method is used for valuations under the Pension Act 2004 and is also knows as Statutory Funding

Objective (SFO) or Funding valuation. The trustees used it to monitor the funding position of the scheme and schedule the contributions of the employer. The trustees also have the responsibility to guarantee the calculations use in the valuation are carried out prudently. The actuaries usually use in the calculation the same discounting rate for all the cashflows no matter the payment date. This discount rate is often higher compared with other methods because it is added an out-performance margin, which corresponds to the risk of the employer, to the risk-free rate i.e. gilt plus margin. Consequently, the liabilities will be lower. This method is the most commonly used for measuring the sensitivities of the liabilities during the internship.

- **Accounting valuation (IAS19)** – International Accounting Standard 19 (IAS19) or Financial Reporting Standard 102 (FRS102) valuation is required to be used by the employer to measure the liabilities of the scheme for the purpose of annual reports and accounts. It typically uses current yields on high corporate bonds as AA rate bonds to calculate the liabilities, not considering how the assets are invested by the scheme´s trustee and using a single equivalent discount rate based on the duration of the cashflows. The main goal of this method it to allow to compare the liabilities of the pension scheme between companies thus the measurement basis is equal to all firms which is set by the relevant accounting standards.
- **PPF buy-out/section 179 basis** – this method, known as Section 179 of the Pension Act 2004, is used to estimate the funding required to assure the PPF levels of compensation. It calculates the amount of levy that all schemes eligible for the protecting of PPF must pay and notifies the PPF7800 index, which defines the estimated funding position every month for all eligible schemes. The PPF will take over the fund in the event of insolvency of the company or when the assets cannot cover the PPF compensation levels, however this is unlikely for most schemes. The assumptions used in this method are the same for all schemes and are defined by the PPF. These assumption are set to closely match the cost of transferring the value of PPF levels of compensation to an insurance company at the date of valuation in case the scheme is takeover by the PPF.
- **Insurance buy-out (Section 75)** – this valuation method estimates the amount of money required to transfer the liabilities to an insurance company. Most schemes don´t have the necessary funding to immediately transfer all its liabilities to an insurance company which is not legally required. However, some plans might adopt a de-risking strategy and transfer liabilities gradually to an insurer, mainly the schemes which are closed to new entrances or close to accrual. When a buy-out occurs, the insurance company has the responsibility to pay all the promised benefits to the member of the scheme. The insurance companies buy low risk assets (high corporate bonds and gilts) to match the liabilities. This method calculates the liabilities with lower discount rates compared with the Technical Provisions method, usually doesn´t add a margin to the interest rate, which will cause the liabilities to be higher. In addition to keep extra assets to meet minimum solvency requirements, the insurance

companies also have to provide profits to their shareholders. Therefore, buying-out all the benefits is very expensive.

- **Self-sufficiency** – under this method the dependence of the scheme to the employer is very low. The investment strategy is usually similar to those made by the insurance companies in case of buy-out (low-risk strategy), except it doesn´t consider the minimum solvency requirements and the profits to the shareholders like the insurance companies. This method might be seen by large schemes as more cost-efficient compared to a buy-out approach with an insurance company. The pension schemes are expected to be sustainable when they achieve a self-sufficient level, simply by maintaining a low-risk investment strategy with no need for extra contributions by the employer.

4.2.2 Actuarial assumptions

In order for the actuaries of the scheme to perform the actuarial valuation they need to establish several assumptions. Defining these assumptions is a very important step to understand the condition and the funding position of the scheme required for trustees to schedule future contributions. The actuarial assumptions are divided in two groups:

Demographic assumptions - related to the participation of the members in the pension scheme i.e. how long will they receive pension benefits. This kind of assumptions are described below [Deloitte (2017)]:

- **Mortality** – the actuaries use mortality tables to estimate the probability of death of the members for each year. In the UK, most schemes use the Continuous Mortality Investigation (CMI) tables. These mortality tables should reflect the profile of the members.
- **Withdrawal rate** – the expected probability of members to leave the pension scheme in each year. A higher withdrawal rate will cause a reduction on the liabilities, since the pension benefits of the members is no longer subject to salary increases.
- **Proportion married** – the actuaries assume that around 80% to 90% of members are married, so in the event of their death the spouse is eligible to a fraction of their pension (in most schemes it is half of the pension benefits).
- **Ill-health retirement** – members that are not able to work due to mental or physical illness, can receive their pension benefits before retirement age.
- **Commutation** – option that the members have to exchange a portion of their pension for a free-tax lump sum. The allowance for commutation causes a reduction in the liabilities.
- **Transfers out** – some members might choose to transfer their benefits out of a DB scheme to another pension scheme.

Economic assumptions - associated to the future economic rates such as the following [Deloitte (2017)]:

- **Discount/interest rate** – this assumption is used to discount the future payment cashflows. The estimating of the discount rate must consider the market

redemption yields on high quality corporate or government bonds, as well as the return of assets that the scheme holds to fund the expect future investment profits and future benefits. There are different methods to estimate the discount rate. The discount rate is usually defined in relation to gilt curves plus a margin, which represents the outperformance of risk-seeking assets that the scheme holds. Most schemes use a dual discount rate, which applies a different rate for pre-retirement and post-retirement discounts. Typically, the pre-retirement discount rate is higher than the post-retirement rate. Other approach is when the discount rate is based on a yield curve instead of a single discount rate. This method allows to discount the project cashflow payments with a different rate for each year which is considered to be more accurate in theory than the single or dual discount rate and in recent years has been adopted by many schemes.

- **Inflation** – it is used to project the increase of future cashflow payments, though revaluation in deferment, salary or pension increases. In a pension scheme, most benefits are linked to the inflation prices, such as the Retail Prices Index (RPI) or the Consumer Prices Index (CPI). The RPI inflation can be measured by the difference between the nominal yields on fixed gilts and real yields on gilts linked to RPI. This method cannot be used to measure the CPI inflation because there are no gilts linked to CPI. So, it is usually estimated by subtracting a margin to RPI inflation. The CPI inflation is often lower than the RPI inflation by 0.7% to 1.0%. An increase in the inflation rate will cause a rise in the projected cashflow payments and therefore an increase in the liabilities.
- **Salary increase** – this assumption indicates the long-term wage of the active members expected by the employer. It is usually specific for each scheme and defined by an agreement between the employer and trustee. It is often linked to RPI inflation plus a margin which can historically range between 0.5% to 1.5%

5. Liability sensitivity analysis

Undoubtedly, DB pension schemes are very risky for employers since they promise their members a certain amount of pension benefits on retirement, which results in a great uncertainty for the employers (contributions to the scheme) and the trustees (ensure the security of pension benefits), since they need to make sure the assets cover the liabilities of the scheme. Even if the scheme is fully funded, the liabilities are very volatile and suffer significant changes over time, so the funding level will also differ. Consequently, the trustees are opting for a new investment strategy, the Liability Benchmark Portfolio (LBP) approach. An LBP is a portfolio of low-risk investments (gilts or high-quality corporate bonds) which are expected to closely match the sensitivity of a pension scheme to fluctuations in interest and inflation, thus decreasing the risk. It has two main elements: the expected benefits payment in each year, which implies the interest rate sensitivity of the liabilities (cashflow profile) and the inflation sensitivity of the liabilities, due to the fact that the pension benefits are linked to interest and inflation

rates. It is not built to account for other factor that can influence the liabilities, as for example changes in the longevity of the members (an increase in longevity causes an increase in liabilities, because members will receive a pension for longer time). In order to create an LBP, the trustee needs to invest in assets which match the sensitivity of the pension scheme´s liabilities.

My task during the internship was to provide an analysis on how the liabilities change against fluctuations in market expectations for the future levels of inflation and interest rates required for the LBP investment approach. In this chapter, there is a deepen explanation of liabilities and risk measures and then a description of the process for analysing the sensitivities of liabilities.

5.1 Liabilities

For the trustees, the liabilities are very important to estimate the funding level, which indicates the proportion of the liabilities that are covered by the scheme´s assets, to ensure that there is enough money at the present to pay the promised benefits in the future. It is important to understand how the liability of a pension scheme is estimated. This task falls on the scheme´s Actuary and it is composed of two main steps. The first step is to project the future payments. As the future benefits are defined by the pension plan, it is possible to forecast the future payments of the pension scheme. By considering the benefits promised by the scheme plan and the actuarial assumptions (like the inflation) the Actuary can estimate the annual payment of the scheme. After this, the Actuary needs to calculate the present value of the future payments, which is the second step. This present value is calculated by using a discount rate, usually a low-risk government bond yield (gilt) plus a margin (as mentioned previously in the economic assumptions), which will discount the future cashflows of a pension scheme and will determine the amount of money needed at the valuation date to cover the cost of the future payments [Insight Investment (2019)]. The present value (liability) is calculated by the following formula:

$$PV = \sum_{t=1}^{T} \frac{CF_t}{(1 + i_t)^t} \tag{2}$$

where:

- CF_t *is the sum of the future cashflows at year* t
- i_t *is the discount rate at year* t
- T *is the last year*

Looking at the formula above, it is easy to understand how the liabilities are changed by variations in the discount rate, which is known by the interest rate risk. If the discount rate decreases, the liability will rise which means that trustee needs more money to ensure the promised benefits. The reverse happens when the discount rate increases, causing a fall in the liability which can be good for the trustee as the amount of assets required to meet the liabilities will be lower. The impact of changes on the discount rate

is illustrated in figure 5, which shows how a decrease in the discount rate from 3% to 2% will cause a rise in the present value but will not change the projected future cashflows.

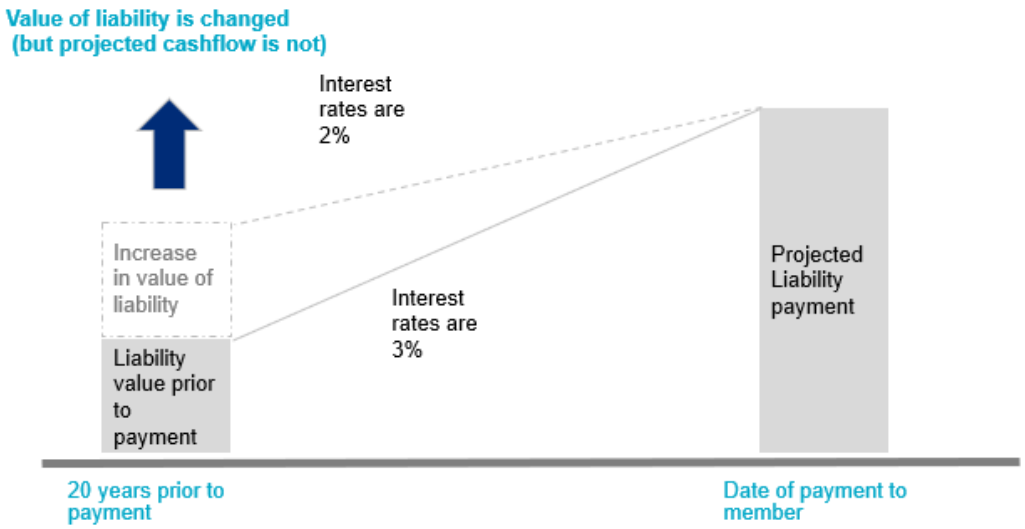

Figure 6: Interest rate risk Source: Mercer (2017)

The interest rate risk will not cause a change in the future projected payments, however the inflation risk will cause a change in both the present value and the future projected cashflows. As a proportion of the scheme´s benefits is linked to the inflation, a change in the inflation rate will affect the amount of projected cashflows estimated by the Actuary. So, a rise in the expected level of future inflation will cause an increase in the projected future payments and consequently a rise in the present value. The opposite occurs in the case of a decrease in the inflation rate [BMO Global Asset Management (2017)]. The following figure shows this change assuming that the discount rate remains unchanged.

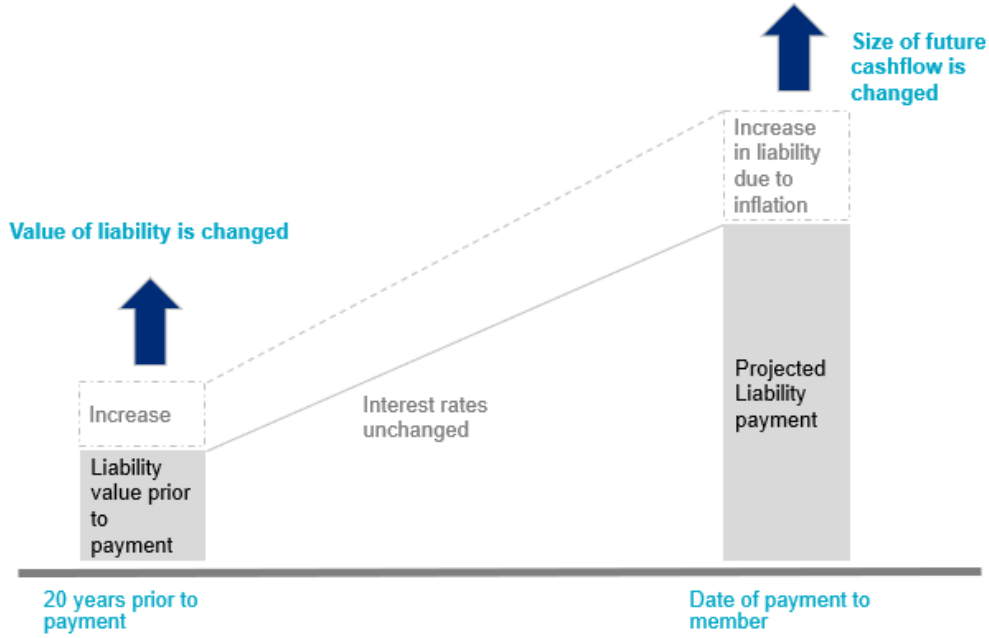

Figure 5: Inflation rate risk Source: Mercer (2017)

5.2 Risk measures

It is important to know why and how the liabilities change with fluctuation of the interest and inflation rates to understand the need for a sensitivity analysis of a pension scheme liability. In fact, those fluctuations can cause significant changes in the liability which will increase the risk of not being able to pay the benefits promised to the pension plan´s members. The liabilities can be separated into groups. The nominal are the liabilities that are only linked to changes in the interest rate, also known as fixed. The real are the liabilities linked to both the interest and inflation rate, also known as index linked. Therefore, it is essential to estimate how the liabilities will change with those fluctuations and there are several risk measures that can be calculated to indicate how sensitive the liabilities are [Mercer (2018b)]. The risk measure used are the following:

- **Duration** – it indicates how the liabilities will change due to a shift in the interest rate, expressed in years, but can be used as a percentage. For example, if the interest rate increases 1% on a liability with 20 years duration, then the liability will fall 20%, where 20 is the value of the duration (as seen previously an increase in the interest rate will result in a decrease of the present value and vice-versa). So, a higher duration will mean a bigger sensitivity of the liabilities to shifts in the interest rate. It is also known as the average term to payment of liabilities. There are various formulas to calculate the duration, the one we use is expressed in the following equation:

$$\text{Duration} = \frac{\sum_{t=1}^{T} t \times \frac{CF_t}{(1+i_t)^t}}{PV} \tag{3}$$

where:

  - CF_t *is the sum of the future cashflows at year* t
  - i_t *is the discount rate at year* t
  - PV *is the total present value*

- **PV01** – like the duration, it is an interest rate risk measure which indicates the negative monetary impact of the liabilities caused by an increase of the interest rate by one basis point (0.01% per annum). This is always a negative value because an increase in the interest rate will cause a fall in the liability. It can be calculated by the following formula:

$$PV01 = PV \times Duration \times 0.01\% \tag{4}$$

- **IE01** – similar to PV01, however it is an inflation risk measure which indicates the change in the value of the liability caused by an increase of the inflation rate by one basis point (0.01% p.a.). There is no simple formula to calculate this, so we need to estimate a new present value, but with an increase in the inflation rate by one basis point and subtract this by the original PV.

- **Delta** – this term is used to indicate the percentage of the liability that is linked to inflation. It is simply calculated by dividing the IE01 by minus PV01 (PV01 is always negative, so we need to turn it in to a positive value). The delta is not an exclusive measure of liability sensitivity and can also be used to determine the inflation linkage of several increases (revaluation, salary or pension increases) linked to inflation, RPI or CPI, with different caps and floors. Usually the floor of each increase is 0%, however there are several types of caps that are applied and it is also important to measure this because if the inflation rate reaches the caps those increases become fixed or nominal. The delta depends on the volatility

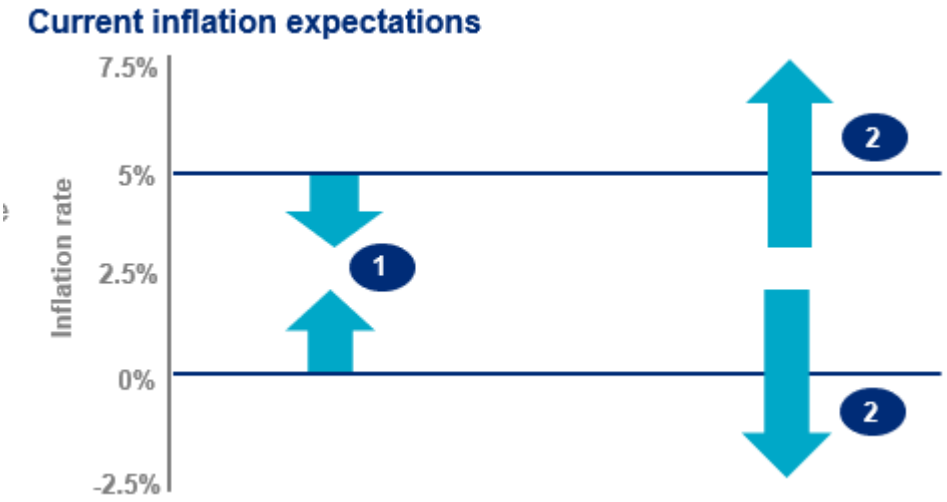

Figure 7: How delta is value Source: Mercer (2019d)

assumed and the current inflation expectations. The picture above helps to illustrate this. The Limited Price Index (LPI) increases (RPI or CPI, but with a cap and floor) are more linked to inflation when the inflation rate is in the middle of the cap and floor, case 1, because it is less likely for the inflation rate to breach the cap and floor (Figure 7). However, if the LPI increase is near or crosses the cap or floor it will be less linked to inflation as it becomes fixed thus with a lower delta, case 2. The Figure 8 shows how the volatility affects the inflation linkage. If the inflation volatility increases, the LPI increase is more fixed in nature as it is

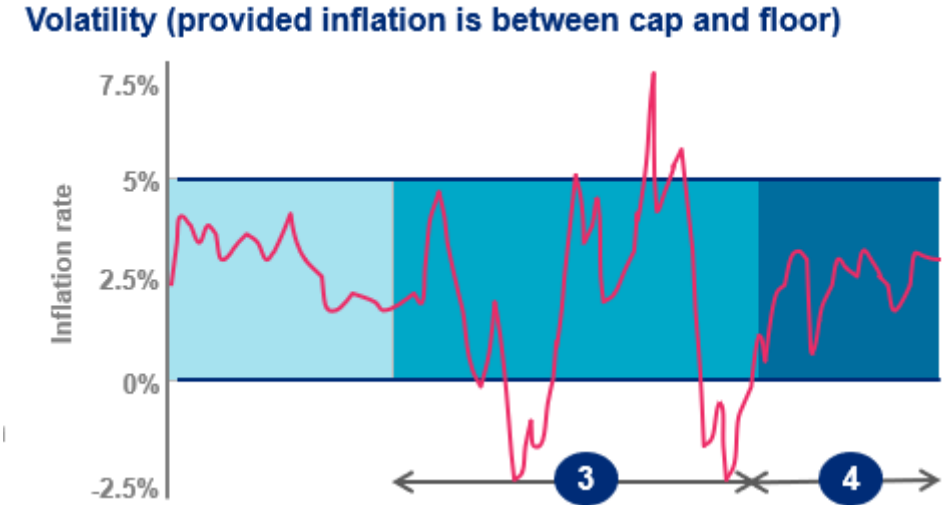

Figure 8: How delta change with volatility Source: Mercer (2019d).

more likely for the inflation rate to reach the cap and floor, case 3. On the other hand, if the inflation volatility decreases, the LPI increase is more real as the probability of reaching the cap and floor is lower, case 4. The delta of the LPI increases are also affected by time. Those deltas decrease over time when the current level of inflation is between the cap and floor. This is due to the diminishing certanty as time goes by. At short tenors it is very unlikely for the inflation rate to reach the cap or floor. However, as time progresses, the inflation levels are more uncertain, so the probability of reaching the cap and floor increases thus decreasing the deltas. This is also caused by the path dependence of inflation which is when the inflation level reachs the cap or floor it is more

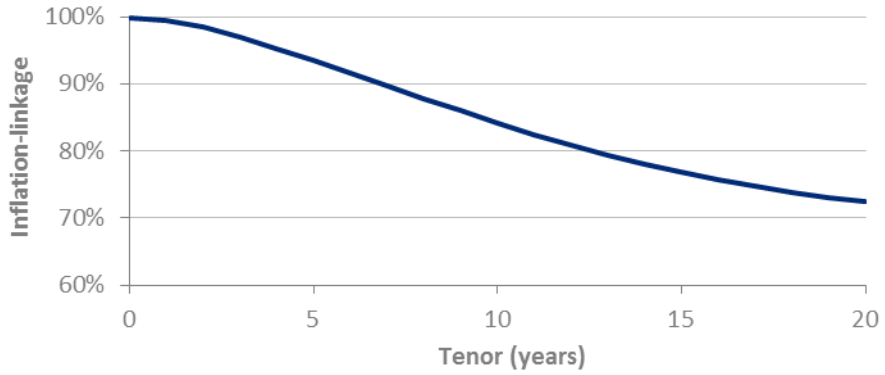

Figure 9: How delta change with time Source: Mercer (2019d)

likely that it will hit the cap and floor the following year. Figure 9 above illustrates this for a LPI increase benefit with 0% floor and 5% cap. The formula to calculate the delta at year t of an LPI increase is the following:

$$delta_t = \frac{LPI\_P_t - LPI_t}{RPI\_P_t - RPI_t} \quad (5)$$

where:

- LPI_P_t *is the LPI rate perturbation* $(i.e.$ *add an inflation marging of* $0.5\%)$ *at year* t
- LPI_t *is the LPI rate at year* t
- RPI_P_t *is the RPI rate perturbation* $(i.e.$ *add an inflation marging of* $0.5\%)$ *at year* t
- RPI_t *is the RPI rate at year* t

5.3 Modelling process

This section describes the process used during the internship to analyse the sensitivity of the liabilities of a pension scheme. This process takes us approximately three to four weeks to complete. There are three workers involved in each project: the Doer, also known as Leader, who is in charge of doing the project (i.e. is the leader of the project); the Checker, who checks if the project is correctly done by the Doer; and the Reviewer, who has more experience in the subject and gives the final approval. In order to produce this project, we used a special software developed by Mercer called the "Gold Tool". The main goal of the Gold Tool is to estimate how the value of the liabilities will shift with changes in future market levels of interest and inflation rates. The purpose of this is that it will be used to identify a portfolio of assets that will mimic the liability

movements as closely as possible and that portfolio is called a Liability Benchmark Portfolio (LBP). The Gold Tool applies a detailed cashflow-based approach, where benefit payments are projected on a year-by-year basis and estimates how the cashflows change under several alternative scenarios for future interest and inflation rates. This year-by-year inflation approach is considered to be very sophisticated to properly understand the structure of benefits linked to inflation which are subject to floors and caps. There are two main reasons why this method is considered superior to others. First it captures the fact that increases before and after retirement could be materially different and second it also captures the fact that future inflation is more uncertain for future years and therefore caps and collars are generally more likely to be hit in those years which in turn reduces the sensitivity to changes in inflation expectations. The Gold Tool splits the cashflows and liabilities into nominal and real as also estimating the inflation and interest sensitivity. The features of the Gold Tool are explained in more detail later.

5.3.1 Cashflows

Our process starts by receiving a request by a Mercer consultant, who is the final "consumer" of our product. The consultant goal is to present an accurate investment strategy to Mercer´s clients. After the request is made, we send them an email with several questions with the information required to perform our analysis. We also receive the cashflow data split by status (Actives, Deferreds and Pensioners) where each column is the year of payment and each row reflects the associated benefit increase by period and all the actuarial assumptions used in the valuation. If the pension scheme is open to accrual, there will be another set of cashflows called the Actives normal cost or future service which represent the cost of having one more year of service.

Sometimes, the actuarial economic assumptions sent are forward rates. In these cases, as Gold Tool only operates with spot rates to reduce the partial year indexation, we need to convert the actuarial rates from forward to spot rate. The spot rate describes the term structure by specifying the current interest rate at any given maturity, whereas the forward rate is one-period future reinvestment rate implied by the current term structure of the spot rate [Vasicek, O. (2015)]. To do this converting by each year of the rate, we must apply the formula below:

$$(1 + f(t,\tau))^{\tau} = \frac{(1 + s(t+\tau))^{(t+\tau)}}{(1 + s(t))^{t}} \tag{6}$$

where:

- $f(t,\tau)\ is\ the\ \tau - year\ foward\ rate\ at\ time\ t$
- $s(t+\tau)\ is\ the\ sport\ rate\ at\ time\ (t+\tau)$
- $s(t)\ is\ the\ spot\ rate\ at\ time\ t$

An important step of our process is to uninflate the cashflows provided, in order to remove the inflation from the actual payments, because the Gold Tool only accepts the cashflows uninflated so it can apply the increases to analyse changes in the market levels

of inflation and interest rates. Appendix 2 shows the uninflated excel spreadsheet where we calculate this. The first step is to apply a time adjustment to the cashflows to consider the benefit payments to be paid at the middle of the year instead of the end, which is a simple multiplication of the first year cashflows by 50% and the following cashflows are calculated by the sum of the cashflow from year *t* and year *t-1* divided by two. Next, we need to fill a table called the "Building Block" with the information of each LPI increases, known as labels, which are associated with the benefits increases in each row of cashflows. This table holds data about how each cashflow should be valued, in both deterministic approach (Actuary checking) and stochastic approach (derivation of sensitivities). The Building Block can be split into two parts which are important to distinguish. The first is used for deterministic PV checks (i.e. comparison with Actuarial present value). This information is the discount rate and actuarial assumptions provided by the Actuary. Those actuarial rates will also be used to uninflate the cashflows. The formula below is applied to uninflate each row of cashflows at different years of payment.

$If\ t < t\_TuD + t\_IDP)\ i.e. pre - retirement\ cashflow$

$$CF_t^u = CF_t^i \times (1 + i_{t\_TuD}^{IuD})^{-t} \tag{7}$$

$otherwise,$

$$CF_t^u = CF_t^i \times (1 + i_{t\_TuD}^{IuD})^{-t\_TuD} \times (1 + i_{t\_TDP}^{IDP})^{-t\_TDP} \times (1 + i_t^{IP})^{-t} \times (1 + i_{(t\_TuD+t\_TDP)}^{IP})^{(t\_TuD+t\_TDP)} \tag{8}$$

where:

- $CF_t^u\ is\ the\ uninflated\ cashflow\ at\ year\ t$
- $CF_t^i\ is\ the\ inflated\ cashflow\ at\ year\ t$
- $i_{t_{TuD}}^{IuD}\ is\ the\ rate\ of\ the\ increase\ until\ decrement\ at\ year\ of\ time\ until\ decrement$
- $i_{t\_TDP}^{IDP}\ is\ the\ rate\ of\ the\ increase\ from\ decrement\ to\ payment\ at\ year\ of\ time \downarrow from\ decrement\ to\ payment$
- $i_t^{IP}\ is\ the\ rate\ of\ the\ increase\ in\ payment\ at\ year\ t$
- $i_{(t\_TuD+t\_TDP)}^{IP}\ is\ the\ rate\ of\ the\ increase\ in\ payment\ at\ year\ of\ time\ until\ decrement \downarrow plus\ time\ from\ decrement\ to\ payment$

The second part will be used to derivate the sensitivity of the cashflows (i.e. stochastic present values and calculation of inflation exposures). This data has two different parts, the one used to estimate the sensitivities and LPI rates called the "Rules for future (LBP hedge derivation)" and another used for the roll forward called "Historic Indexation" which is essential, because the cashflows are at the date of valuation and we need to estimate the value of those cashflows at a future date. These are all explained below. The data from the "Rules for future (LBP hedge derivation)" are the following [Mercer (2018a)]:

- **Labels** – the name given to the LPI increases which are associated to the cashflows. Each name needs to be unique.

- **InfPercent** – the percentage in which the LPI increases is linked to inflation. It is usually 0% for fixed/nominal increases and 100% for inflation-linked increases. However, in some specific cases other percentages may fit (such as 66% or 33%).
- **InfMargin** – the gap between the RPI rate and the LPI increase assumption. In labels linked to CPI, it should reflect the difference between CPI and RPI, while an RPI linked label will have a 0% margin. For other RPI linked labels, for example S148 or salary increases could be set as RPI minus or plus the margin. In some cases, we need to allow for Inflation Risk Premium (IRP) and add it for all labels.
- **InfMin** – the floor of each LPI increase which is usually set to 0% as we don´t assume negative increases.
- **InfMax** – the caps of each label. It varies depending of the different labels set up. When the label is uncapped it should be set to 99%.
- **Type** – decides how the Gold Tool will simulate the future inflation. It has two different inputs, 1 or 2. Type 1 stands for year-on-year application, while type 2 represents a cumulative assumption path, which means that the minimum and maximum are applied cumulatively over the term since time zero. Normally, the revaluations are set as type 2 and pension increases as type 1.

The parameters from the "Historic Indexation" are described below:

- **Inflation Switch Date (Type 1 to Type 2)** – the date when the pension scheme switched from RPI to CPI revaluation, usually set to 30 September 2010.
- **Inflation Type 1 and Inflation Type 2** – is the inflation index that is associated with the label which can be one of four centrally updated inflation indices (RPI, CPI, NAE and Average Weekly Earnings [AWE]), or even a custom historic inflation. The Inflation Type 1 is the index applied up to the "Inflation Switch Date" and Inflation Type 2 is another index used afterwards.
- **LastAnniversary** – is the date of the last pension increase allowed in the cashflows at valuation date (inflation lag). It is very important because it specifies the level of inflation increases that are already applied to the cashflows. During the roll-forward any historical revaluations, as well as subsequent revaluations and pension increases will be made with reference to this date.
- **ApplyPercent** – used to specify if the "InfPercent" is applied to the historical revaluations and future increases during roll-forward. This input is always set to "TRUE"
- **ApplyMargin** – used to specify whether the "InfMargin" is applied to the historical revaluations and future increases during roll-forward. It is used for CPI linked benefits and should be defined as "FALSE". In addition, AWE linked benefits are also set to "FALSE". For example, if CPI indexation is setup to be modelled as "RPI-0.7%" in the stochastic valuation model (i.e. "InfMargin" = -0.7%) then the "ApplyMargin" should be set to "FALSE" because we want it to apply historical increases in line with actual CPI index without any adjustment.

After everything is properly filled, the spreadsheet will calculate the uninflated cashflows and we can advance to the next step of the process.

5.3.2 Input

In this part of the process, we have to fill an excel spreadsheet called the "Input spreadsheet", which contains all the information needed to derive the sensitivities of the liabilities and will be loaded to the Gold Tool. The Input spreadsheet is shown in Appendix 3. There are several inputs that can be filled, although on this part of the process there are five key input data type objects that must be filled [Mercer (2018d)]:

- **Audit** – the purpose of this tab is to store main client information together with audit trail of what has been done and checked. Most of this information will not have a direct impact on the sensitivity analysis and are only used for project identification and general information. However, the "Project as-at date" is the only part of the data inputs which has a relevant impact on the calculation itself as it specifies the effective date of cashflows (valuation date), which is important for roll-forwards (although it can be over-written on each 3D cashflow sheet separately, if needed).
- **BuildingBlock** – holds indexation information for each tranche of benefits, as well as actuarial valuation assumptions. As we have already produced a Building Block table in the uninflated spreadsheet, we only have to copy that one to the Input spreadsheet. In the cases when the period between the valuation and analysis date is equal or higher than one year, we need to add more Building blocks depending on the year of roll-forward. This has to do with the programming methods of Gold Tool itself and will be explained in the next section.
- **3D Cashflow** – All cashflows provided by the Actuary from the uninflated spreadsheet that are in the uninflated (real) format. Each row of the cashflow represents a benefit tranche characterised by the following periods: "Time since leaving" (usually only used for deferred members); "Time until decrement" (not used at the moment and therefore set to zero); "Time until payment"; "Time until retirement" which is used in cases when pre and post-retirement are different and so "Time until payment" is different from "Time until retirement". For each period of time we must specify the type of increase to be applied over the period, which is done by specifying the name of the indexation associated on the BuildingBlock. In the cases when there are pre-retirement cashflows (i.e. when the year of payment of the cashflows is inferior to the "Time until payment"), the Gold Tool will separate these cashflows from the rest (post retirement cashflows).
- **LPI Model Parameters** – control the volatility of the inflation which impacts the level of LPI curves and thus influences the present value of LPI benefits. it contains two alpha and two sigma values (one for nominal and one for real) and one rho parameter (correlation). There are three different volatility parameters: Central, Lower and Higher. We need to set the parameters accordingly with the volatility assumption requested in the email (usually it is the Central volatility assumption). These assumptions are estimated on a quarterly basis by another Mercer team.

- **Yield Curves** – where we set the current market yield curves that will be used in the analysis plus the requested margin. Usually we fill two different curves, one at valuation date and other at analysis date.

5.3.3 Gold Tool

When all these five key inputs are filled, we can then load it to the Gold Tool. The interface of Gold Tool can be seen in Appendix 4. This interface is split into the following seven main tabs [Mercer (2018d)]:

- **General Settings** – stores general information about the project, gets a quick overview of all objects (cashflows, building block, yield curves and more) used in the project and specifies a path to the MATLAB library folder.
- **Preliminary** – used for some initial cashflow manipulation processes, such as combining several cashflows together or rolling cashflows forward over time. New cashflows are generated as result of this process.
- **LPB Derivation** – used to generate the estimations of the sensitivity of the liability value to interest and inflation rates under market conditions at a given point in time.
- **HAT (RISK)** – where the effectiveness of LBPs and other user-specified "LBP Bonds" are tested against the underlying liabilities. It is strongly recommended to run all final LBPs through HAT to check the effectiveness of the hedge, especially if the LBP will be used for implementation.
- **Charts** – used to plot various charts from the analysis when populating the deck which is a PowerPoint presentation with details information explaining how the LBP was derived, the assumptions underlying it and the circumstances under which it should be reviewed.
- **LDI Roll** – used to roll forward LBP Bonds (previous estimations generated on the "LBP Derivation" tab) over time, which is a useful feature to monitor an LBP at various points in time. It is important to understand that rolling forward the LBP Bonds is different from rolling forward the 3D Cashflows.
- **LDI Analysis** – used to plot charts to compare cashflows, PVs, PV01s & IE01 of various Portfolios simultaneously.

The first three tabs are the most important and are explained in more detail in this section. On the other hand, the other tabs are only used when a deck or additional analysis are requested and will not be further explained because it wasn´t part of the activities performed in the internship. Before importing the Input spreadsheet, we need to select the local copy of the MATLAB library path which is a collection of *.mat files that hold a database of historical yield curves and inflation indices necessary to run the sensitivity analysis. When loading the Input spreadsheet, the Gold Tool will perform a deterministic run where it calculates its own present value of the cashflows imported called the "Model PV". It uses the actuarial assumptions from the Building Block to inflate and discount the cashflows and compares this "Model PV" with the actual present value provided by the actuary. This is a test to check if the previous steps were

done correctly as we expect the difference between those two present values to be lower than 1%. For further analysis of this deterministic run we can export an excel spreadsheet called "Step1" spreadsheet where we can do another check to compare the Model PV against the Actuaries PV line-by-line. This can all be seen in the "General Settings" of the Gold tool. In this tab we can also add new "Yield Curves" and "LPI Model Parameters" without having to create them in the Input spreadsheet and load it again. We can then advance to the cashflows manipulation in the "Preliminary" tab of the Gold Tool. In this tab we can take one or more existing 3D Cashflows as an input, to create a new 3D Cashflow object to be used later on. It has four basic processes to manipulate the cashflows which I explain below [Mercer (2018d)]:

- **Basis Switch** – alter the Building Block information associated with the 3D Cashflows used to estimate the "Model PV". It is used to check the present value of the 3D Cashflows under an alternative valuation basis. Not usually used.
- **Truncate CFs** – used to reduce the number of rows in the 3D Cashflow to improve the calculation times of LBP Hedge and HAT. When the 3D Cashflow includes large number of rows with insignificant (close to zero) present values it will negatively impact calculation times of LBP Hedge and HAT. The eliminating of a proportion of the cashflow data will reduce the number of rows in the 3D Cashflows, as well as the impact on the total present value. The "PV Correction" will ensure the total PV of the manipulated 3D Cashflow is the same as the PV of the original cashflows by scaling the remaining cashflows up to the original PV. Not usually used.
- **Combine CFs** – used to combine several 3D Cashflow together into a single Cashflow object. The combination of 3D Cashflows must have the same valuation date and BuildingBlock associated. We usually used this function to combine all the past service 3D Cashflows (Active, Deferred and Pensioner) to get the Total cashflows.
- **Roll Forward** – used to apply known increases to the 3D cashflows to move the cashflows forward in time applying the data in the "Historic Indexation" of the Building Block table. The software will break up the roll forward period into whole year rolls followed by a partial-year roll. For example, a 2.50 years roll forward will be done in three steps: two yearly rolls and a partial roll for 0.50 years at the end. For each roll forward step, we need to specify the correct Building Block that should be used to reference the appropriate indexation. As mentioned before, if the period between the analysis and valuation date (i.e. the roll forward period) is equal or higher than one year we need to add a new Building Block and add years to the "LastAnniversary" column. When performing a roll forwards for less than 1 year, the base BuildingBlock should be used because any partial year roll forwards are performed by referencing the "LastAnniversary" as the start date of the indexation. However, when performing roll forwards for exactly 1 year up to 1.99 years, we should select a new Building Block where we add one year to the "LastAnniversary" column. It

will perform the roll-forward in two steps, first applying one-year worth of increases by referencing the 12-month index change prior “LastAnniversary” date of the new Building Block and then a partial year roll forward by applying increases from that date onwards. For roll-forwards with exactly 2 years up to 2.99 years, we need to create and select two Building Blocks. In the first one we have to add one year to the “LastAnniversary” date and it will be used for the first year roll forward (referencing 12 months increases prior to the anniversary date plus one year). The second BuildingBlock we have to add two year to the “LastAnniversary” date and it will be used to firstly apply another 12 months of increases (by referencing 12 months prior to the anniversary date plus two year) and then partial year increases from that date onwards. For longer roll forward periods we should apply the same approach. This is an essential step as we need to move the cashflows forward in time to the analysis date for a more accurate and current sensitive analysis.

The next phase is to estimate the sensitivity of the liabilities in the “LBP Derivation” tab. In each estimation called LBP Hedge we need to specify the type of cashflows, yield curve, LPI Model, numbers of simulations and size of perturbation. The higher number of simulations, which is used to estimate the LPI curves, the higher the level of accuracy and smoothness of the hedge, however it will take longer to perform the calculations. These inputs depend on the request from the consultant, but we typically we run all types of cashflows (Active, Deferred, Pensioner and Total) with Central volatility, full simulation and 50 basis points of perturbation. We run this “LPB Hedges” with two different yield curves, one at valuation date for checking purposes and other at analysis date which is the final output requested by the consultant. Then the software will proceed to derivate the sensitivities of the liabilities. The process behind it is the following. First, it uses its own internal module to price the LPI benefits called the LPI Pricer. The current level of inflation and the assumed level of inflation volatility, which helps to determine the probability of reaching the floors and caps in the future, are the main parameters which influence the pricing of LPI benefits. The LPI Pricer applies a stochastic model based at the Jarrow Yildrum (JY) model [Mercer (2018d)] to estimate the LPI curves, which is basically two Hull and White models, one for nominal rates and one for real rates that provide an implied process for inflation. It uses the parameters from the “LPI Model”, where the sigma can be interpreted as the volatility of the short rate and the alpha is a mean reversion term, that impacts on how quickly the short rate simulation paths tend back to a central path and also determines the relationship within the model between the volatility of shorter and longer dated bonds, which are tied together with a correlation factor rho [Mercer (2018b)]. The inflation simulations are derived as the difference between nominal and real simulations. It uses a Monte-Carlo simulation to project nominal and real yields over several simulations (usually 10,000), calibrated so that nominal and real yield projections are consistent with market data. It will then apply the floors and cap to each simulation and will take an average to generate the LPI curves. The following figure illustrates this process.

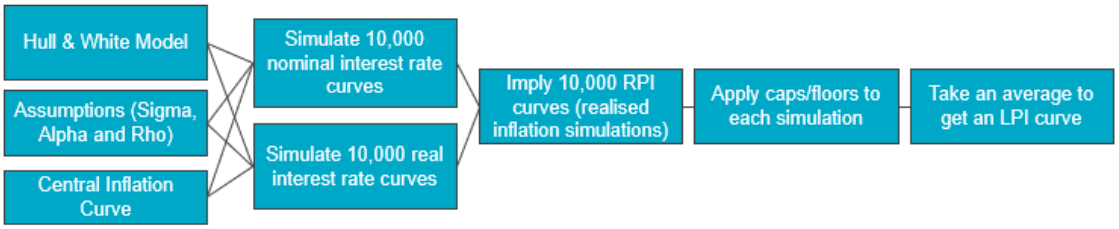

Figure 10: How the LPI Pricer works Source Mercer (2018b)

Afterwards, the Gold Tool will calculate the central value of liabilities using the initial level of inflation priced using the LPI Pricer. Then it perturbs the year 1 forward inflation curve by the "Perturbation size", often +50 bps, and reprice the liabilities; in other words it feeds the perturbed curve to the LPI Pricer and uses it to find the new value of liabilities, which allows it to calculate sensitivity of liabilities to the year 1 inflation forward. It repeats this calculation, but with the inflation curve derived as the central curve + 50bps applied to the year 1 and 2 forwards. Repeats the calculation again, but with the inflation curve derived as the central curve + 50bps applied to year 1, 2 and 3 forwards. It will continue to repeat the calculation with the forward curve perturbation all the way to year 120, which will result in 120 different inflation perturbation scenarios, each associated with a new value of liabilities. It then calculates 120 liability sensitivities (i.e. the percentage change in liabilities (relative to central PV) in each of the 120 inflation scenarios described above). It produces the inflation exposure inherent in liabilities in each of the 120 years along the curve. This is combined with the interest and inflation rate exposure to generate a portfolio of zero-coupon nominal and real bonds called the "LBP". This process is illustrated in the following figure:

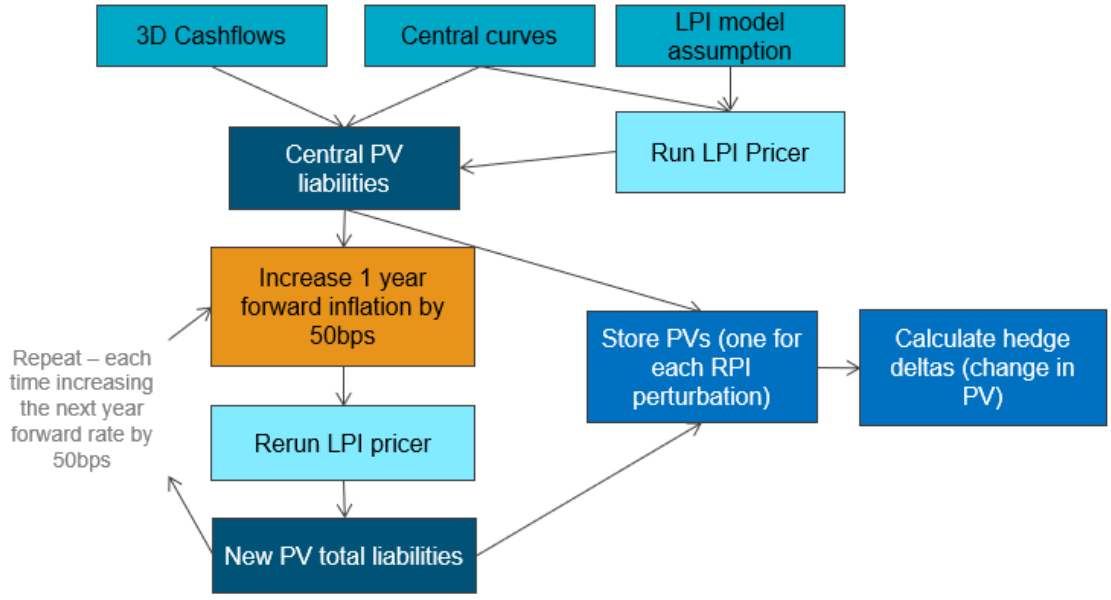

Figure 11 How the Gold Tool works Source: Mercer (2018b)

The results can then be exported to an excel spreadsheet called the Output spreadsheet for further analysis.

5.3.4 Checks and Output

The Output spreadsheet contains all the information on the cashflows and liabilities sensitivities and it is the final product we deliver to the consultants so they are able to build an LBP. The Output spreadsheet contains several sensitivity data like the cashflows split into nominal, real inflated, real uninflated and total; the present values also split by nominal and real; PV01s and IE01s both in spot and forward; specify inputs of the LBP Hegde such as LPI model, cashflows date and yield curve date which help identify each run. There are some figures of the Output spreadsheet in Appendix 5 to have a better understanding of the data it contains. Before we can send these results to the consultant, we need to do numerous checks to ensure the process and estimations have been done correctly and no mistake has been made along all the steps. We have another excel spreadsheet to helps perform this check and to prove the analysis was done properly called the Checker spreadsheet which can be seen in Appendix 6. In this spreadsheet, we used the LBP Hedges run at valuation date to compare with the data provided by the Actuary and check the consistency with the previous liability sensitivity analysis, with the Actuarial valuation present value, with the Actuarial valuation sensitivities and with pension increase split. Besides this, we also calculate the roll forward of the LBP Hegde at valuation date to the date of analysis to check if the Gold Tool roll forward the cashflows correctly. After all the check are performed, the Checker and the Reviewer will look at the analysis and when they are comfortable with the results, we can then send the Output spreadsheet to the consultants. As said previously, the consultants can also request further analysis or a PowerPoint presentation (called a Deck) with more sensitivities analysis to show to the client, although those activities were not part of my tasks during the internship. In addition, the consultants can also ask for us to make some adjustments for external factors to the analysis, such as the actual cashflows that have been paid, especially for the values of the members that transferred out of the scheme, adjust for the inflation lag and other factors like the GMP Equalisation, for example. The consultant, working alongside with the investment team, will invest the assets in zero coupon gilts, which are government bonds from the UK, with similar sensitivities to those of the liabilities for different maturities and therefore protecting the liabilities to changes in interest and inflation rate to ensure that there is enough money to pay the retirement benefits when they are due. When the liabilities and assets behave differently to changes in the interest and inflation rate, the deficit of the funding level will increase if the interest rate falls, for example. When there is no hedging, if the liabilities rise, the assets will not change and the deficit will increase. On the other hand, when there is 100% hedging, an increase in the liabilities will cause an increase in the assets in the same value while the deficit remains the same. The figure 12 illustrates this.

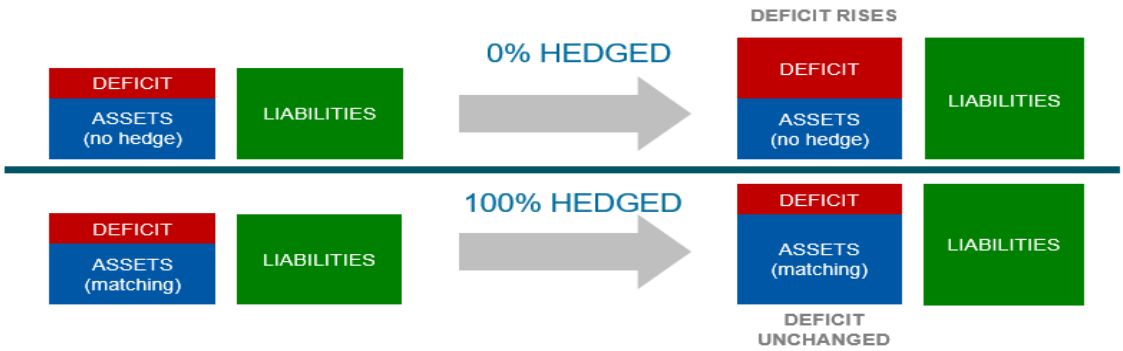

Figure 12: Liability Hedge Source: Mercer (2019b)

Most clients that implement an LBP follow a Liability Driven Investment (LDI) strategy. This strategy can be split into two parts. The Growth part which consists in investing a proportion of the assets in riskier financial instruments, such as equity funds, so that they can generate investment return. As some schemes are underfunded, there is this need to generate return to reduce the funding gap of the scheme. The amount of assets that will be used for growth will depend on the amount of the deficit and the risk tolerance. The other part of the LDI strategy is the Matching component. This is where the remaining assets will be invested in low risk financial instruments, such as bonds, to match the sensitivity of the liabilities and help manage the interest and inflation risk. The LBP will be implemented in this part of the LDI strategy. However, it is worth notice that in the real world it is difficult to find financial instruments to invest in, which have the same sensitivity as the liabilities, so it is hard to build a portfolio where the liabilities are 100% hedged. In other cases, the trustees might not want to hedge all the liabilities as part of the investment strategy, for example when the interest rate is very low and it is expected that it will rise, the trustees choose not to fully hedge the liabilities because an increase in the interest rate will result in a decrease in the liabilities, so they don´t want the assets to fall in the same proportion. Therefore, the LBP is frequently used, as the name suggests, as a benchmark on how the portfolio of matching assets should perform.

6. Conclusion

This internship was a very rewarding experience as I had the opportunity to have my first professional experience and to learn more about pension funds, especially in the UK, develop my soft skills and expand my knowledge in Excel. The liability sensitivity analysis performed during the internship is very important for the implementation of an investment strategy which consists in building a portfolio that will mimic the liability movements of the pension scheme as closely as possible. As the liabilities of a pension scheme will change when there are shifts in the inflation and interest rate, this kind of investment strategy will reduce the risk exposure to these changes. Therefore, the trustees are opting for this investment strategy to achieve their goal of ensuring there is enough money in the trust account to pay the promised retirement benefits to the members of the pension scheme. Although this analysis is considered to be very sophisticated and capable of closely matching the movement of the liabilities to changes in the interest and inflation rate, there are some limitations in this process. For active members, which have three periods with different inflation linkage (Time from valuation to decrement; Time from decrement to payment; Time from payment), the Gold Tool is only able to handle two periods of indexations, so the first two periods (time from valuation to decrement and time from decrement to payment) have to be merged and a single indexation was assumed for those periods which will result on an analysis which will not be as accurate as intended. Currently, there is a project to update the Gold Tool so it can handle these three indexation periods and consequently making it a more accurate approach. Another feature being developed is the ability to slip the inflation linkage benefits into those that are linked to RPI and those that are linked to CPI. These new features will contribute for the consolidation and accuracy of the Gold Tool thus allowing for a more accurate and efficient analysis. Another limitation of the LBP approach is related to the shortage of government bonds. The supply of some bonds, especially long-term index-linked gilts, can be very low and unpredictable, since it depends of the UK government need to issue debt [BMO Global Asset Management (2017)]. Also, most UK government bonds that are available have short maturities and there are a small number of long-term bonds available in the market. As an LBP is composed of zero coupon government bonds, this scarcity will affect the investment strategy and result in a change on the asset allocation to accommodate this limitation, despite the advantages of using government bonds (low risk investment). Due to these limitations, trustees are opting to invest in swaps instead of bonds, given that swaps are more flexible and are available in almost all maturities up to 50 years. Also, there is no supply issue with the swaps as in the case of the government bonds. Therefore, swaps are considered a good alternative to bonds, mainly to match the long-term liabilities. Even with these limitations, the LBP approach is still considered a very sophisticated and effective method to hedge the liabilities, thus reducing the risk associated with DB pension schemes and ensuring that each member of the pension scheme will receive the benefits promised at retirement.

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Appendix 1: Indexation periods

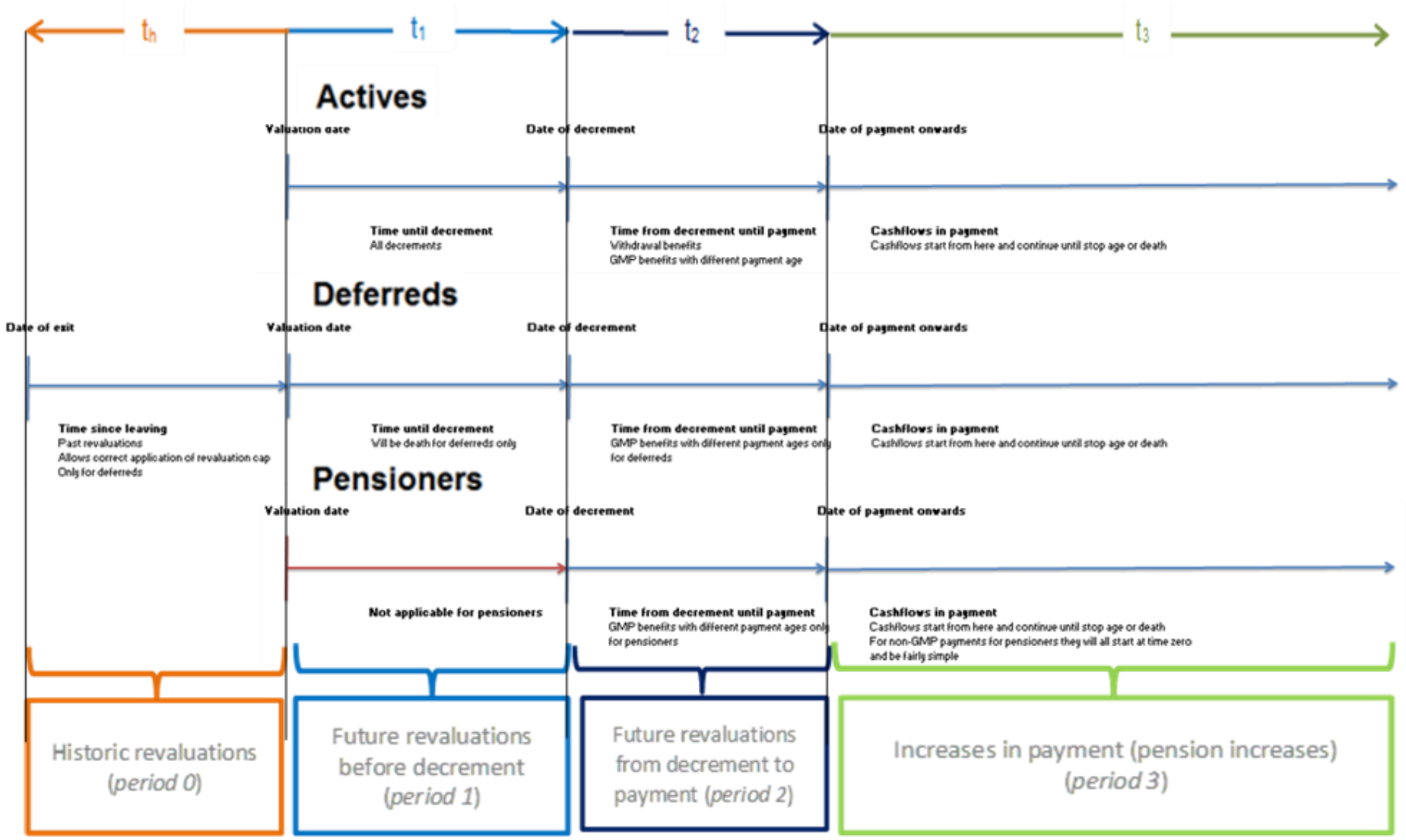


Figure 13: Indexation periods Source: Author

Appendix 2: Uninflated spreadsheet

Actuarial PV	51,019,415												
						82,709,844							
Time until decrement	Time from decrement to payment	Time since leaving	Increases until decrement	Increases from decrement to payment	Increases in payment	0	1	2	3	4	5	6
0	0	0	0%	0%	0%	6	7	7	8	8	9	9
0	0	0	0%	0%	0%	93	82	88	94	101	108	116
0	0	0	Reval_CPI25	0%	PI_CPI25	0	0	0	0	0	0	0
0	0	0	Reval_CPI25	0%	PI_CPI25	4	4	4	4	4	4	4
0	0	0	Reval_CPI5	0%	PI_CPI25	1	1	1	1	1	1	1
0	0	0	Reval_CPI5	0%	PI_CPI25	5	6	6	6	6	6	6
0	0	0	Reval_CPI5	0%	PI_CPI5	0	0	0	0	0	0	0
0	0	0	Reval_CPI5	0%	PI_CPI5	4	4	4	4	5	5	5
0	0	1	0%	0%	0%	43	46	49	52	55	58	60
0	0	1	0%	0%	0%	30	33	35	37	40	43	46
0	0	1	Reval_CPI25	0%	PI_CPI25	1	1	1	1	1	1	1
0	0	1	Reval_CPI25	0%	PI_CPI25	0	0	0	0	0	0	0
0	0	1	Reval_CPI5	0%	PI_CPI25	2	2	2	2	2	2	2
0	0	1	Reval_CPI5	0%	PI_CPI25	1	1	1	1	1	1	1
0	0	1	Reval_CPI5	0%	PI_CPI5	3	3	3	3	3	3	3
0	0	1	Reval_CPI5	0%	PI_CPI5	17	17	17	18	18	18	19
0	0	1	Reval_CPI5	0%	PI_Fixed0	1	1	1	1	1	1	1
0	0	1	Reval_CPI5	0%	PI_Fixed0	0	0	0	0	0	0	0
0	0	1	Reval_FixedGMP	0%	PI_CPI3	0	0	0	0	0	0	0
0	0	1	Reval_FixedGMP	0%	PI_CPI3	0	0	0	0	0	0	0
0	0	2	0%	0%	0%	18	20	21	23	25	26	28
0	0	2	0%	0%	0%	21	23	25	26	28	30	32
0	0	2	Reval_CPI25	0%	PI_CPI25	1	1	1	1	1	1	1
0	0	2	Reval_CPI5	0%	PI_CPI25	2	2	2	2	2	2	2
0	0	2	Reval_CPI5	0%	PI_CPI5	3	3	3	3	3	3	3
0	0	2	Reval_CPI5	0%	PI_Fixed0	4	4	4	4	4	4	4
0	0	3	0%	0%	0%	30	32	34	35	37	39	40
0	0	3	0%	0%	0%	265	283	304	326	327	338	363
0	0	3	Reval_CPI25	0%	PI_CPI25	1	1	1	1	1	1	1
0	0	3	Reval_CPI25	0%	PI_CPI25	10	10	10	10	11	11	11
0	0	3	Reval_CPI5	0%	PI_CPI25	2	2	2	2	3	3	3
0	0	3	Reval_CPI5	0%	PI_CPI25	19	19	20	20	20	21	21
0	0	3	Reval_CPI5	0%	PI_CPI5	1	1	1	1	1	1	1
0	0	3	Reval_CPI5	0%	PI_CPI5	18	18	19	19	20	20	21
0	0	3	Reval_CPI5	0%	PI_Fixed0	2	2	2	2	2	2	2
0	0	3	Reval_FixedGMP	0%	PI_CPI3	0	0	0	0	0	0	0
0	0	4	0%	0%	0%	66	69	72	75	78	81	85
0	0	4	0%	0%	0%	343	355	381	409	269	287	308
0	0	4	Reval_CPI25	0%	PI_CPI25	2	2	2	2	2	2	2
0	0	4	Reval_CPI25	0%	PI_CPI25	7	7	8	8	8	8	8
0	0	4	Reval_CPI5	0%	PI_CPI25	5	5	5	5	5	5	6
0	0	4	Reval_CPI5	0%	PI_CPI25	17	17	17	18	18	18	18
0	0	4	Reval_CPI5	0%	PI_CPI5	0	0	0	0	0	0	0
0	0	4	Reval_CPI5	0%	PI_CPI5	20	21	21	22	22	23	23
0	0	4	Reval_CPI5	0%	PI_Fixed0	2	2	2	2	2	2	2
0	0	4	Reval_CPI5	0%	PI_Fixed0	7	7	7	7	7	7	7
0	0	4	Reval_FixedGMP	0%	PI_CPI3	2	2	2	2	2	2	2
0	0	4	Reval_FixedGMP	0%	PI_Fixed0	0	0	0	0	0	0	0

Figure 14: Cashflows received from the Actuary Source: Author

Scheme name [redacted]
Valuation Date 31/03/2018

DISCOUNT RATE	Actuarial assumption, annualy compounding spot rate as at time t = ...														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Pre retirement	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%
Post retirement	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%	1.85%

			Rules for future (LBP hedge derivation)						Historic Indexation						Actuarial assumption, annualy compounding spot rate		
Check labels	Check Margin	Index	Label	InfPercent	InfMargin	InfMin	InfMax	Type	Inflation Type 1	Inflation Type 2	Inflation Switch Date (Type 1 to Type 2)	LastAnniversary	ApplyPercent	ApplyMargin	1	2	
1	TRUE	1	0%	0.00%	0.00%	0.00%	0.00%	1	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	0.00%	0.00%	0.00%
1	TRUE	2	Fully Salary Increase	100.00%	0.00%	0.00%	99.00%	1	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	3.30%	3.30%	3.30%
1	TRUE	3	Not Fully Salary Increa	0.00%	0.00%	0.00%	0.00%	1	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	0.00%	0.00%	0.00%
1	TRUE	4	PI_CPI25	100.00%	-0.80%	0.00%	2.50%	1	CPI	CPI	30/09/2010	30/09/2017	TRUE	FALSE	1.80%	1.80%	1.80%
1	TRUE	5	PI_CPI3	100.00%	-0.80%	0.00%	3.00%	1	CPI	CPI	30/09/2010	30/09/2017	TRUE	FALSE	2.00%	2.00%	2.00%
1	TRUE	6	PI_CPI5	100.00%	-0.80%	0.00%	5.00%	1	CPI	CPI	30/09/2010	30/09/2017	TRUE	FALSE	2.45%	2.45%	2.45%
1	TRUE	7	PI_Fixed0	0.00%	0.00%	0.00%	0.00%	1	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	0.00%	0.00%	0.00%
1	TRUE	8	PI_Fixed5	0.00%	0.00%	0.00%	0.00%	1	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	0.00%	0.00%	0.00%
1	TRUE	9	PI_RPI5	100.00%	0.00%	0.00%	5.00%	1	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	3.10%	3.10%	3.10%
1	TRUE	10	Reval_CPI25	100.00%	-0.80%	0.00%	2.50%	2	RPI	CPI	30/09/2010	30/09/2017	TRUE	FALSE	2.50%	2.50%	2.50%
1	TRUE	11	Reval_CPI5	100.00%	-0.80%	0.00%	5.00%	2	RPI	CPI	30/09/2010	30/09/2017	TRUE	FALSE	2.50%	2.50%	2.50%
1	TRUE	12	Reval_FixedGMP	0.00%	0.00%	0.00%	0.00%	2	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	0.00%	0.00%	0.00%
1	FALSE	13	Reval_LimitedGMP	100.00%	0.00%	0.00%	5.00%	2	AWE	AWE	30/09/2010	30/09/2017	TRUE	FALSE	3.30%	3.30%	3.30%
1	FALSE	14	Reval_S148	100.00%	0.00%	0.00%	99.00%	1	AWE	AWE	30/09/2010	30/09/2017	TRUE	FALSE	3.30%	3.30%	3.30%
1	FALSE	15															
1	FALSE	16															
1	FALSE	17															
1	FALSE	18															
1	FALSE	19															
1	FALSE	20															
1	FALSE	21															
1	FALSE	22															
1	FALSE	23															
1	FALSE	24															
1	FALSE	25															
1	FALSE	26															
1	FALSE	27															

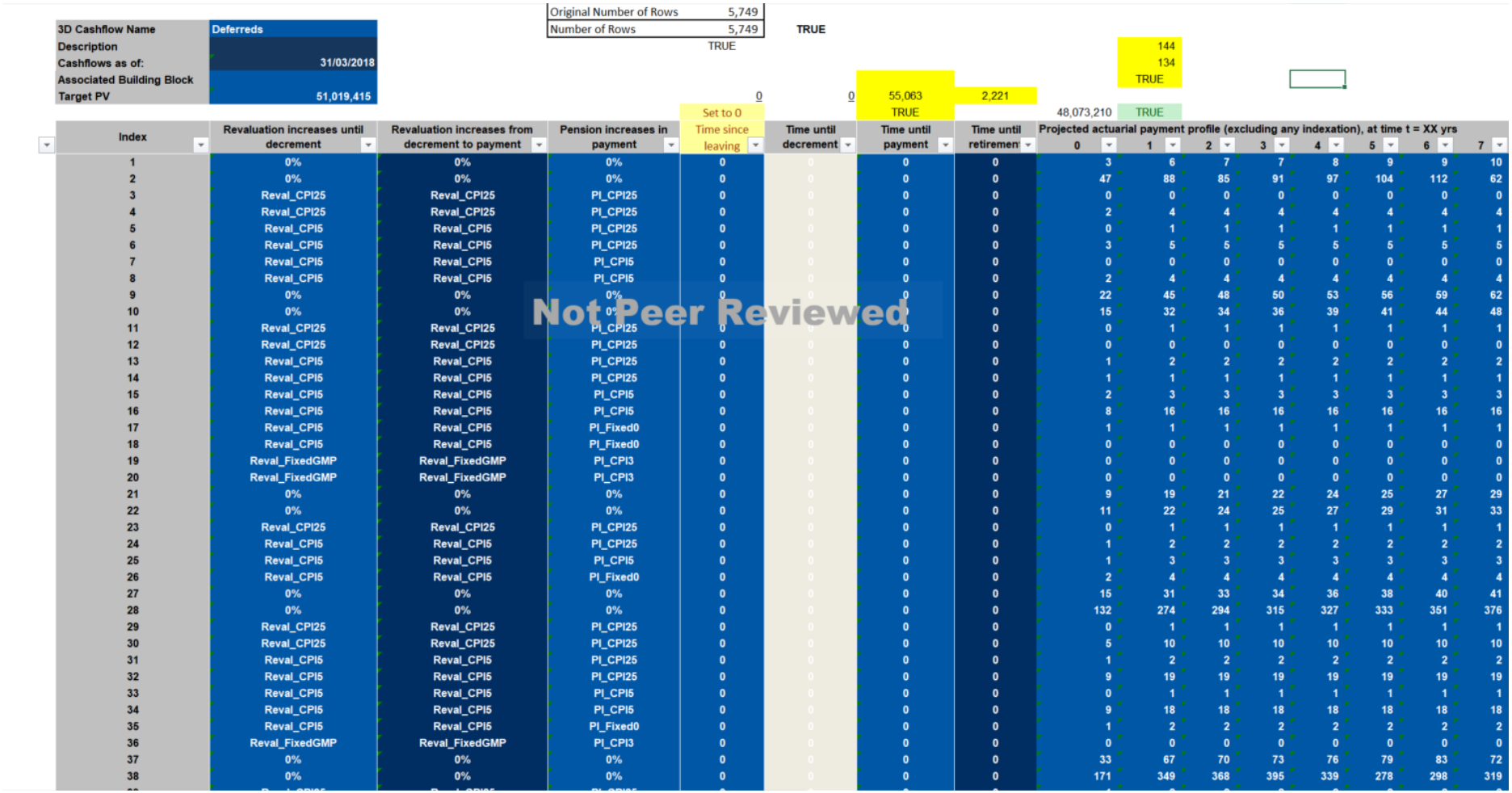
Figure 15: Discount rate and Actuarial Assumptions Source: Author

1 Stage 1 Output		Original Number of	5,749												
A		Number of Rows	5,749	TRUE											
		Cashflow Name		55063	TRUE		82,709,844	0							

Remember to fill down formulas

Index	Increases until decrement	Increases from decrement to payment	Increases in payment	Time until decrement	Time from decrement to payment	Time since leaving	Projected actuarial payment profile (excluding any indexation), at time t = XX yrs							
							0	1	2	3	4	5	6	7
1	0%	0%	0%	0	0	0	3	6	7	7	8	9	9	10
2	0%	0%	0%	0	0	0	47	88	85	91	97	104	112	62
3	Reval_CPI25	0%	PI_CPI25	0	0	0	0	0	0	0	0	0	0	0
4	Reval_CPI25	0%	PI_CPI25	0	0	0	2	4	4	4	4	4	4	4
5	Reval_CPI5	0%	PI_CPI25	0	0	0	0	1	1	1	1	1	1	1
6	Reval_CPI5	0%	PI_CPI25	0	0	0	3	6	6	6	6	6	6	6
7	Reval_CPI5	0%	PI_CPI5	0	0	0	0	0	0	0	0	0	0	0
8	Reval_CPI5	0%	PI_CPI5	0	0	0	2	4	4	4	4	5	5	5
9	0%	0%	0%	0	0	1	22	45	48	50	53	56	59	62
10	0%	0%	0%	0	0	1	17	34	36	36	39	41	44	48
11	Reval_CPI25	0%	PI_CPI25	0	0	1	0	1	1	1	1	1	1	1
12	Reval_CPI25	0%	PI_CPI25	0	0	1	0	0	0	0	0	0	0	0
13	Reval_CPI5	0%	PI_CPI25	0	0	1	1	2	2	2	2	2	2	2
14	Reval_CPI5	0%	PI_CPI25	0	0	1	1	1	1	1	1	1	1	1
15	Reval_CPI5	0%	PI_CPI5	0	0	1	2	3	3	3	3	3	3	4
16	Reval_CPI5	0%	PI_CPI5	0	0	1	8	17	17	17	18	18	19	19
17	Reval_CPI5	0%	PI_Fixed0	0	0	1	1	1	1	1	1	1	1	1
18	Reval_CPI5	0%	PI_Fixed0	0	0	1	0	0	0	0	0	0	0	0
19	Reval_FixedGMP	0%	PI_CPI3	0	0	1	0	0	0	0	0	0	0	0
20	Reval_FixedGMP	0%	PI_CPI3	0	0	1	0	0	0	0	0	0	0	0
21	0%	0%	0%	0	0	2	9	19	21	22	24	25	27	29
22	0%	0%	0%	0	0	2	11	22	24	25	27	29	31	33
23	Reval_CPI25	0%	PI_CPI25	0	0	2	0	1	1	1	1	1	1	1
24	Reval_CPI5	0%	PI_CPI25	0	0	2	1	2	2	2	2	2	2	2
25	Reval_CPI5	0%	PI_CPI5	0	0	2	1	3	3	3	3	3	3	3
26	Reval_CPI5	0%	PI_Fixed0	0	0	2	2	4	4	4	4	4	4	4
27	0%	0%	0%	0	0	3	15	31	33	34	36	38	40	41
28	0%	0%	0%	0	0	3	132	274	294	315	327	333	351	376
29	Reval_CPI25	0%	PI_CPI25	0	0	3	0	1	1	1	1	1	1	1
30	Reval_CPI25	0%	PI_CPI25	0	0	3	5	10	10	10	10	11	11	11
31	Reval_CPI5	0%	PI_CPI25	0	0	3	1	2	2	2	3	3	3	3
32	Reval_CPI5	0%	PI_CPI25	0	0	3	9	19	19	20	20	20	21	21
33	Reval_CPI5	0%	PI_CPI5	0	0	3	0	1	1	1	1	1	1	1
34	Reval_CPI5	0%	PI_CPI5	0	0	3	9	18	19	19	20	20	20	21
35	Reval_CPI5	0%	PI_Fixed0	0	0	3	1	2	2	2	2	2	2	2
36	Reval_FixedGMP	0%	PI_CPI3	0	0	3	0	0	0	0	0	0	0	0
37	0%	0%	0%	0	0	4	33	67	70	73	76	79	83	72

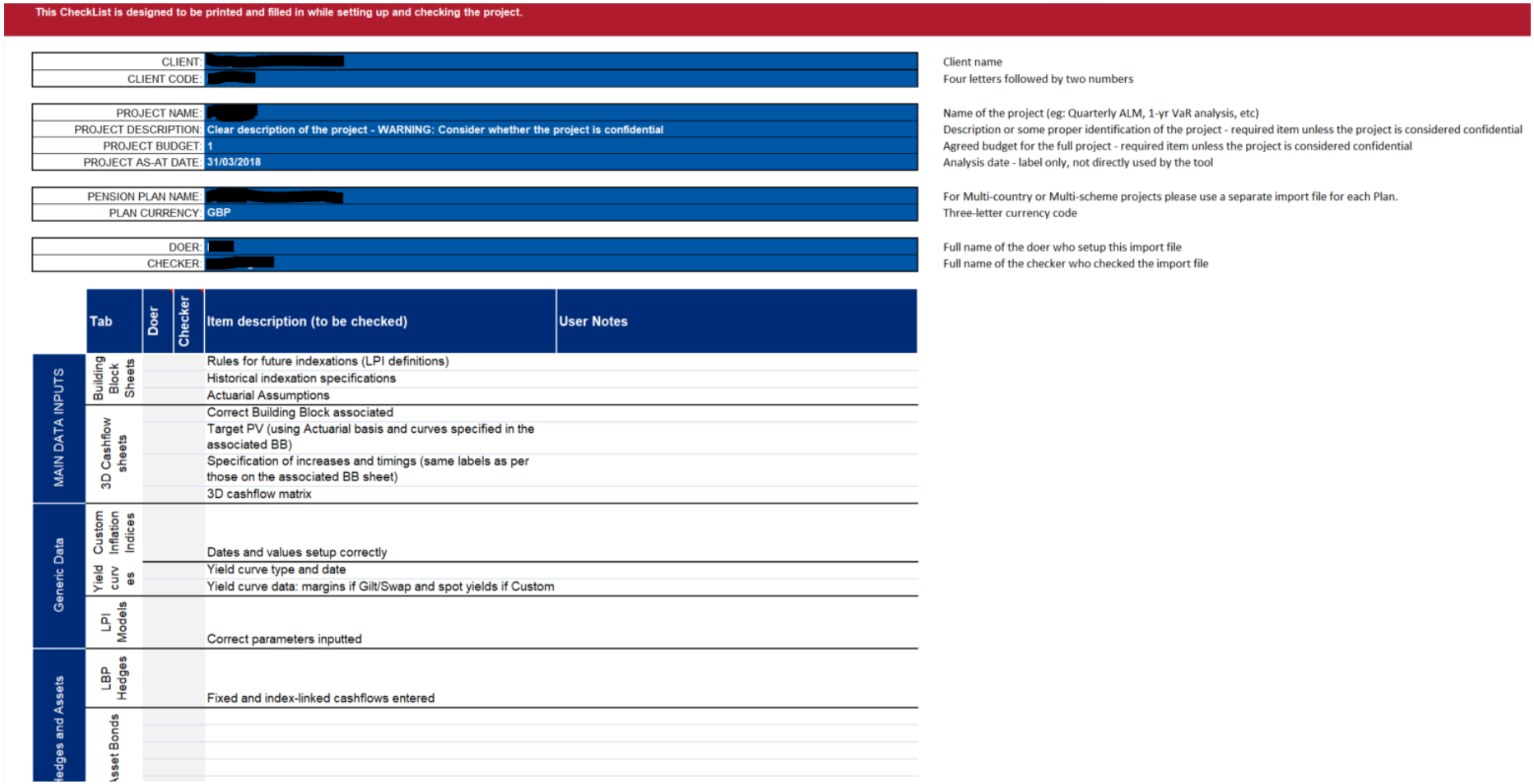
Figure 16: Cashflow half time adjustment Source: Author



3D Cashflow Name	Deferreds			Original Number of Rows	5,749												
Description				Number of Rows	5,749	TRUE							144				
Cashflows as of:	31/03/2018				TRUE								134				
Associated Building Block													TRUE				
Target PV	51,019,415				0	0	55,063	2,221									
					Set to 0		TRUE		48,073,210	TRUE							
Index	Revaluation increases until decrement	Revaluation increases from decrement to payment	Pension increases in payment	Time since leaving	Time until decrement	Time until payment	Time until retiremen	Projected actuarial payment profile (excluding any indexation), at time t = XX yrs									
								0	1	2	3	4	5	6	7		
1	0%	0%	0%	0	0	0	0	3	6	7	7	8	9	9	10		
2	0%	0%	0%	0	0	0	0	47	88	85	91	97	104	112	62		
3	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	0	0	0	0	0	0	0	0		
4	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	2	4	4	4	4	4	4	4		
5	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	0	1	1	1	1	1	1	1		
6	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	3	5	5	5	5	5	5	5		
7	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	0	0	0	0	0	0	0	0		
8	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	2	4	4	4	4	4	4	4		
9	0%	0%	0%	0	0	0	0	22	45	48	50	53	56	59	62		
10	0%	0%	0%	0	0	0	0	15	32	34	36	39	41	44	48		
11	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	0	1	1	1	1	1	1	1		
12	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	0	0	0	0	0	0	0	0		
13	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	1	2	2	2	2	2	2	2		
14	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	1	1	1	1	1	1	1	1		
15	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	2	3	3	3	3	3	3	3		
16	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	8	16	16	16	16	16	16	16		
17	Reval_CPI5	Reval_CPI5	PI_Fixed0	0	0	0	0	1	1	1	1	1	1	1	1		
18	Reval_CPI5	Reval_CPI5	PI_Fixed0	0	0	0	0	0	0	0	0	0	0	0	0		
19	Reval_FixedGMP	Reval_FixedGMP	PI_CPI3	0	0	0	0	0	0	0	0	0	0	0	0		
20	Reval_FixedGMP	Reval_FixedGMP	PI_CPI3	0	0	0	0	0	0	0	0	0	0	0	0		
21	0%	0%	0%	0	0	0	0	9	19	21	22	24	25	27	29		
22	0%	0%	0%	0	0	0	0	11	22	24	25	27	29	31	33		
23	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	0	1	1	1	1	1	1	1		
24	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	1	2	2	2	2	2	2	2		
25	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	1	3	3	3	3	3	3	3		
26	Reval_CPI5	Reval_CPI5	PI_Fixed0	0	0	0	0	2	4	4	4	4	4	4	4		
27	0%	0%	0%	0	0	0	0	15	31	33	34	36	38	40	41		
28	0%	0%	0%	0	0	0	0	132	274	294	315	327	333	351	376		
29	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	0	1	1	1	1	1	1	1		
30	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	5	10	10	10	10	10	10	10		
31	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	1	2	2	2	2	2	2	2		
32	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	9	19	19	19	19	19	19	19		
33	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	0	1	1	1	1	1	1	1		
34	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	9	18	18	18	18	18	18	18		
35	Reval_CPI5	Reval_CPI5	PI_Fixed0	0	0	0	0	1	2	2	2	2	2	2	2		
36	Reval_FixedGMP	Reval_FixedGMP	PI_CPI3	0	0	0	0	0	0	0	0	0	0	0	0		
37	0%	0%	0%	0	0	0	0	33	67	70	73	76	79	83	72		
38	0%	0%	0%	0	0	0	0	171	349	368	395	339	278	298	319		

Figure 17: Sheet to uninflate the cashflows Source: Author

Appendix 3: Input spreadsheet



This CheckList is designed to be printed and filled in while setting up and checking the project.

CLIENT:	[redacted]	Client name
CLIENT CODE:	[redacted]	Four letters followed by two numbers
PROJECT NAME:	[redacted]	Name of the project (eg: Quarterly ALM, 1-yr VaR analysis, etc)
PROJECT DESCRIPTION:	Clear description of the project - WARNING: Consider whether the project is confidential	Description or some proper identification of the project - required item unless the project is considered confidential
PROJECT BUDGET:	1	Agreed budget for the full project - required item unless the project is considered confidential
PROJECT AS-AT DATE:	31/03/2018	Analysis date - label only, not directly used by the tool
PENSION PLAN NAME:	[redacted]	For Multi-country or Multi-scheme projects please use a separate import file for each Plan.
PLAN CURRENCY:	GBP	Three-letter currency code
DOER:	[redacted]	Full name of the doer who setup this import file
CHECKER:	[redacted]	Full name of the checker who checked the import file

	Tab	Doer	Checker	Item description (to be checked)	User Notes
MAIN DATA INPUTS	Building Block Sheets			Rules for future indexations (LPI definitions)	
				Historical indexation specifications	
				Actuarial Assumptions	
	3D Cashflow sheets			Correct Building Block associated	
				Target PV (using Actuarial basis and curves specified in the associated BB)	
				Specification of increases and timings (same labels as per those on the associated BB sheet)	
				3D cashflow matrix	
Generic Data	Custom Inflation Indices			Dates and values setup correctly	
	Yield curves			Yield curve type and date	
				Yield curve data: margins if Gilt/Swap and spot yields if Custom	
	LPI Models			Correct parameters inputted	
Hedges and Assets	LBP Hedges			Fixed and index-linked cashflows entered	
	Asset Bonds				

Figure 18: Audit sheet Source: Author

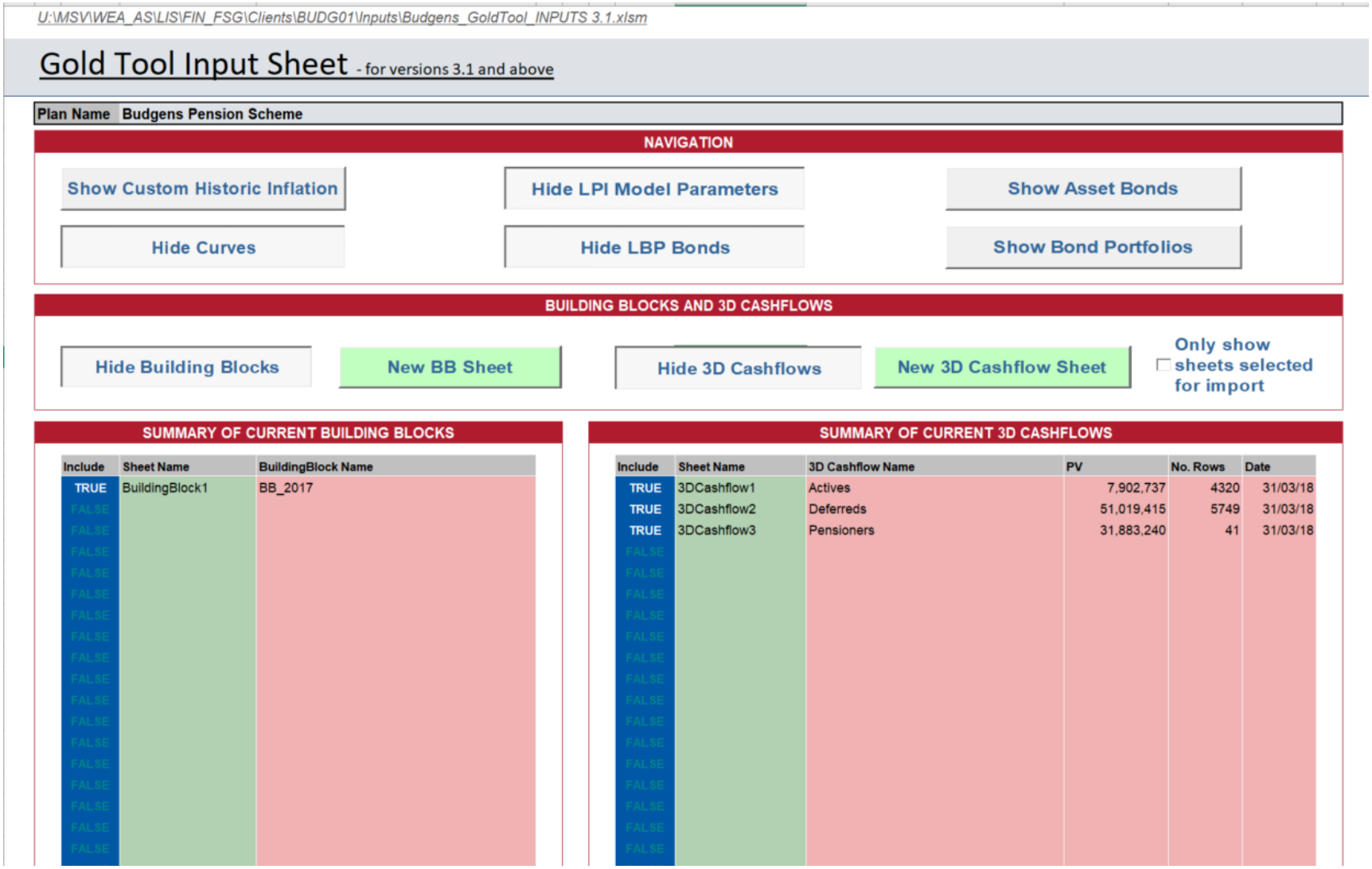


Figure 19: Main sheet (summary of the inputs) Source: Author

3D Cashflow Name	Deferreds
Description	Deferreds
Cashflows as of:	31/03/2018
Associated Building Block	BB_2017
Target PV	51,019,415

number of rows: 5749

Clone 3D Cashflows | Go to Main

Index	Revaluation increases until decrement	Revaluation increases from decrement to payment	Pension increases in payment	Time since leaving	Time until decrement	Time until payment	Time until retirement	Projected actuarial payment profile (excluding any indexation), at time t = XX yrs				
								0	1	2	3	4
1	0%	0%	0%	0	0	0	0	3	6	7	7	8
2	0%	0%	0%	0	0	0	0	47	88	85	91	97
3	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	0	0	0	0	0
4	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	2	4	4	4	4
5	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	0	1	1	1	1
6	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	3	5	5	5	5
7	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	0	0	0	0	0
8	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	2	4	4	4	4
9	0%	0%	0%	0	0	0	0	22	45	48	50	53
10	0%	0%	0%	0	0	0	0	15	32	34	36	39
11	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	0	1	1	1	1
12	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	0	0	0	0	0
13	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	1	2	2	2	2
14	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	1	1	1	1	1
15	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	2	3	3	3	3
16	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	8	16	16	16	16
17	Reval_CPI5	Reval_CPI5	PI_Fixed0	0	0	0	0	1	1	1	1	1
18	Reval_CPI5	Reval_CPI5	PI_Fixed0	0	0	0	0	0	0	0	0	0
19	Reval_FixedGMP	Reval_FixedGMP	PI_CPI3	0	0	0	0	0	0	0	0	0
20	Reval_FixedGMP	Reval_FixedGMP	PI_CPI3	0	0	0	0	0	0	0	0	0
21	0%	0%	0%	0	0	0	0	9	19	21	22	24
22	0%	0%	0%	0	0	0	0	11	22	24	25	27
23	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	0	1	1	1	1
24	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	1	2	2	2	2
25	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	1	3	3	3	3
26	Reval_CPI5	Reval_CPI5	PI_Fixed0	0	0	0	0	2	4	4	4	4
27	0%	0%	0%	0	0	0	0	15	31	33	34	36
28	0%	0%	0%	0	0	0	0	132	274	294	315	327
29	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	0	1	1	1	1
30	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	5	10	10	10	10
31	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	1	2	2	2	2
32	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	9	19	19	19	19
33	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	0	1	1	1	1
34	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	9	18	18	18	18
35	Reval_CPI5	Reval_CPI5	PI_Fixed0	0	0	0	0	1	2	2	2	2
36	Reval_FixedGMP	Reval_FixedGMP	PI_CPI3	0	0	0	0	0	0	0	0	0
37	0%	0%	0%	0	0	0	0	33	67	70	73	76
38	0%	0%	0%	0	0	0	0	171	349	368	395	339
39	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	1	2	2	2	2
40	Reval_CPI25	Reval_CPI25	PI_CPI25	0	0	0	0	4	7	7	7	7
41	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	3	5	5	5	5
42	Reval_CPI5	Reval_CPI5	PI_CPI25	0	0	0	0	8	17	17	17	17
43	Reval_CPI5	Reval_CPI5	PI_CPI5	0	0	0	0	0	0	0	0	0

Figure 20: Uninflated cashflows for Gold Tool Source: Author

BuildingBlock Name	BB_2017
Description	BB_2017
number of rows:	14

Clone Building Block | Go to Main

These inputs are only us

	Actuarial assumption, a	
DISCOUNT RATE	1	2
Pre retirement	1.85%	1.85%
Post retirement	1.85%	1.85%

		Rules for future (LBP hedge derivation)					Historic Indexation						Actuarial assumption, a	
Index	Label	InfPercent	InfMargin	InfMin	InfMax	Type	Inflation Type 1	Inflation Type 2	Inflation Switch Date (Type 1 to Type 2)	LastAnniversary	ApplyPercent	ApplyMargin	1	2
1	0%	0.00%	0.00%	0.00%	0.00%	1	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	0.00%	0.00%
2	Fully Salary Increase	100.00%	0.00%	0.00%	99.00%	1	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	3.30%	3.30%
3	Not Fully Salary Increase	0.00%	0.00%	0.00%	0.00%	1	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	0.00%	0.00%
4	PI_CPI25	100.00%	-0.80%	0.00%	2.50%	1	CPI	CPI	30/09/2010	30/09/2017	TRUE	FALSE	1.80%	1.80%
5	PI_CPI3	100.00%	-0.80%	0.00%	3.00%	1	CPI	CPI	30/09/2010	30/09/2017	TRUE	FALSE	2.00%	2.00%
6	PI_CPI5	100.00%	-0.80%	0.00%	5.00%	1	CPI	CPI	30/09/2010	30/09/2017	TRUE	FALSE	2.45%	2.45%
7	PI_Fixed0	0.00%	0.00%	0.00%	0.00%	1	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	0.00%	0.00%
8	PI_Fixed5	0.00%	0.00%	0.00%	0.00%	1	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	0.00%	0.00%
9	PI_RPI5	100.00%	0.00%	0.00%	5.00%	1	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	3.10%	3.10%
10	Reval_CPI25	100.00%	-0.80%	0.00%	2.50%	2	RPI	CPI	30/09/2010	30/09/2017	TRUE	FALSE	2.50%	2.50%
11	Reval_CPI5	100.00%	-0.80%	0.00%	5.00%	2	RPI	CPI	30/09/2010	30/09/2017	TRUE	FALSE	2.50%	2.50%
12	Reval_FixedGMP	0.00%	0.00%	0.00%	0.00%	2	RPI	RPI	30/09/2010	30/09/2017	TRUE	TRUE	0.00%	0.00%
13	Reval_LimitedGMP	100.00%	0.00%	0.00%	5.00%	2	AWE	AWE	30/09/2010	30/09/2017	TRUE	FALSE	3.30%	3.30%
14	Reval_S148	100.00%	0.00%	0.00%	99.00%	1	AWE	AWE	30/09/2010	30/09/2017	TRUE	FALSE	3.30%	3.30%
15														
16														
17														
18														
19														
20														
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														
31														
32														
33														
34														
35														
36														

Figure 21: Building Block Source: Author

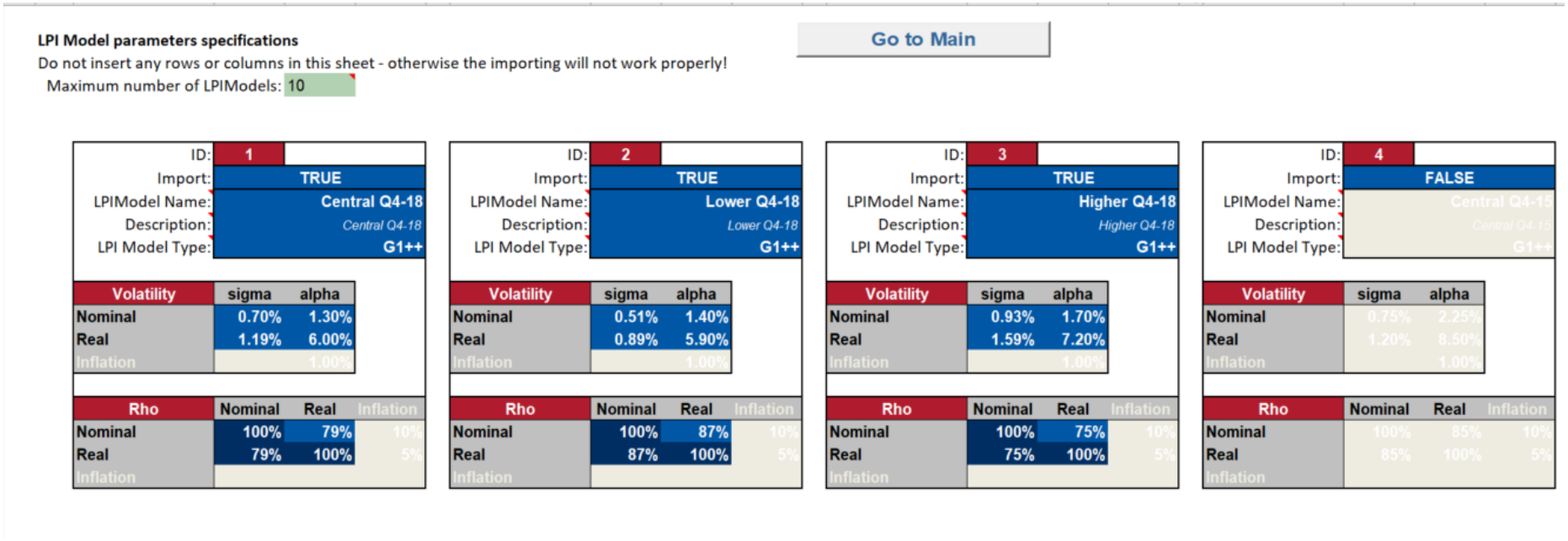


Figure 22: LPI Model Parameters Source: Author

Yield Curve specifications

Go to Main

All yield inputs are specified as annually compounded zero-coupon spot rates.
Inputs are in nominal and real terms, inflation is derived internally as "(1+nom) / (1+real) - 1".
Do not insert any rows or columns in this sheet - otherwise the importing will not work properly!

Maximum number of curves: 10

	1	2	3	4
Import:	TRUE	TRUE	FALSE	
Curve Name:	Gilt 30Mar18	Gilt 31Jan19	Gilt 31/12/2015	
Curve Description:	*Gilt 30Mar18*	*Gilt 31Jan19*		
Curve Type:	Gilt	Gilt	Gilt	
As at Date:	30/03/2018	31/01/2019	31/12/2015	
	As at date used to lookup from Matlab library	*As at date used to lookup from Matlab library*	*As at date used to lookup from Matlab library*	*As at date used to lo*

	1		2		3		4
	Annually compounded MARGINS		Annually compounded MARGINS		Annually compounded MARGINS		
	Nominal	Inflation	Nominal	Inflation	Nominal	Inflation	
0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1
2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2
3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3
4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4
5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5
6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6
7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7
8	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9
10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10
11	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11
12	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	12
13	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13
14	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	14
15	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	15
16	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16
17	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	17
18	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	18
19	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	19
20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20
21	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	21
22	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	22
23	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	23

Figure 23: Curves Source: Author

Appendix 4: Gold Tool layout

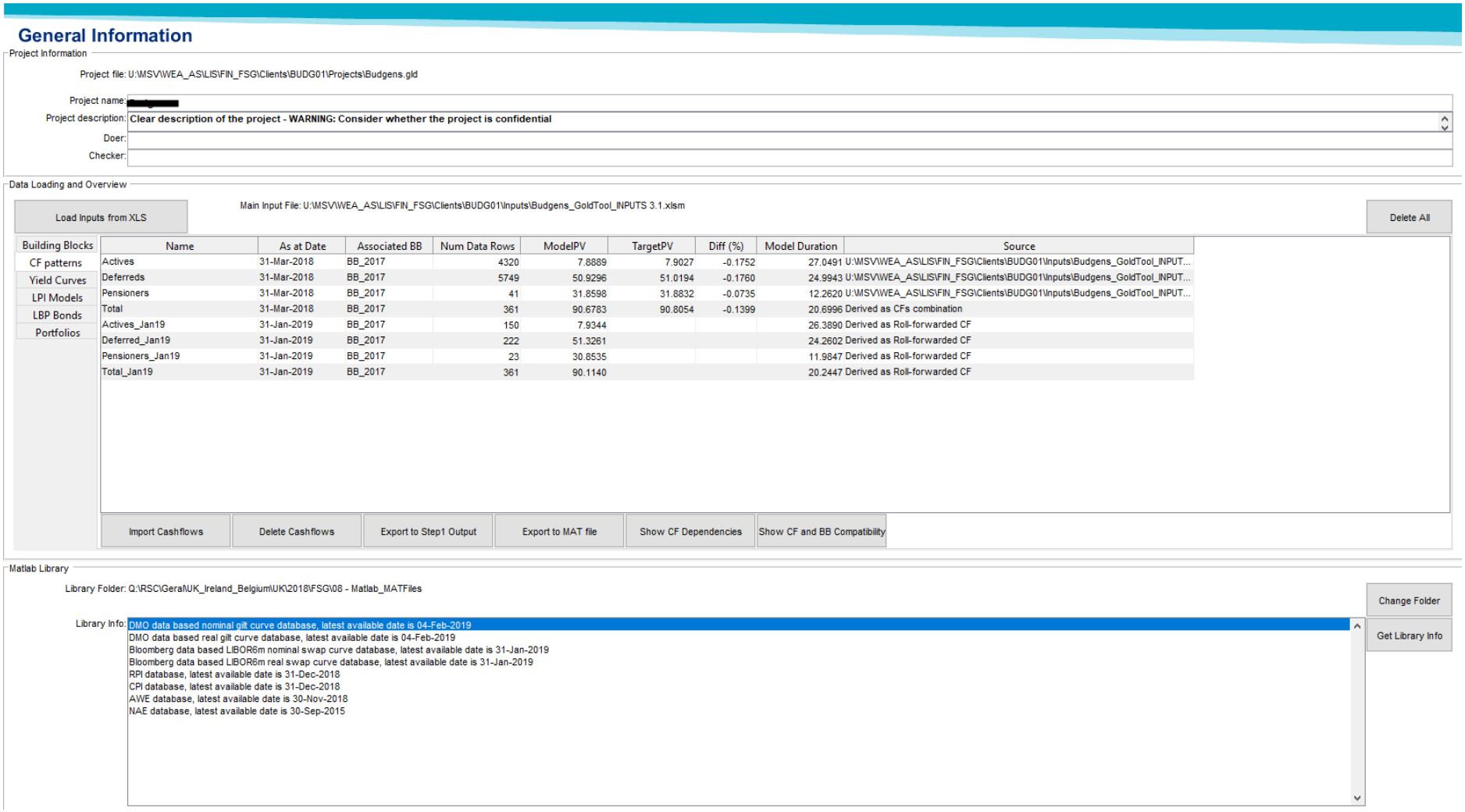


Figure 24: General Settings Source: Author

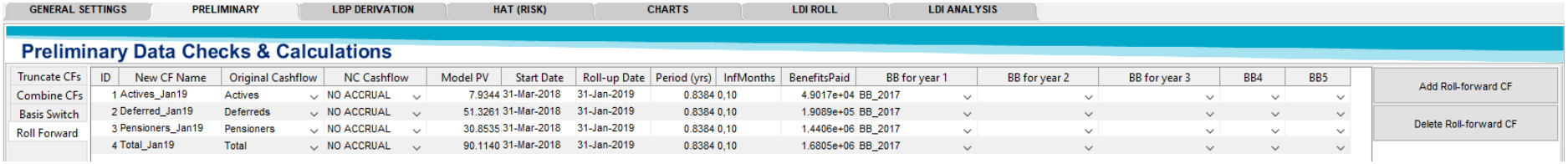


Figure 25: Preliminary Source: Author

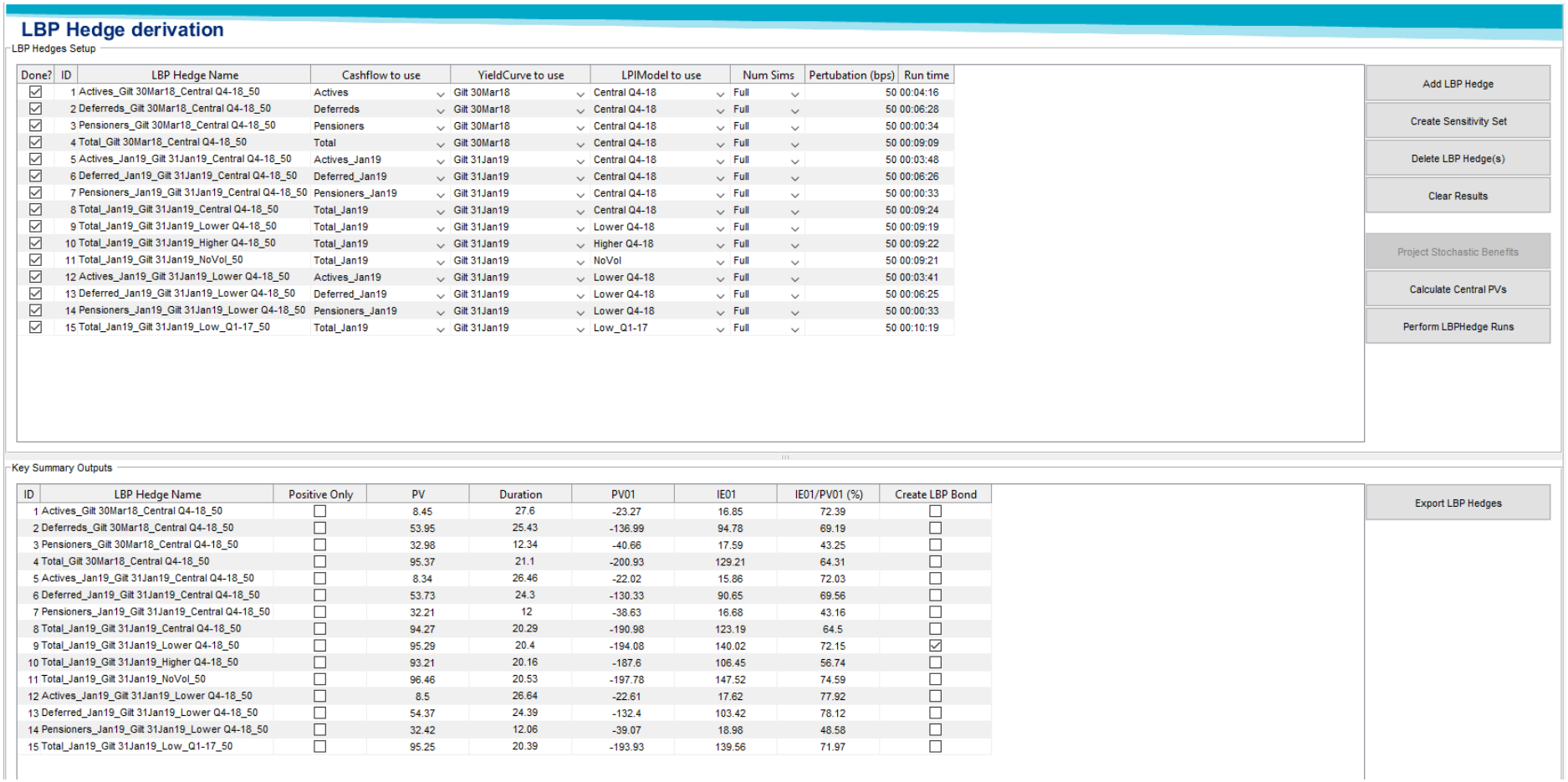
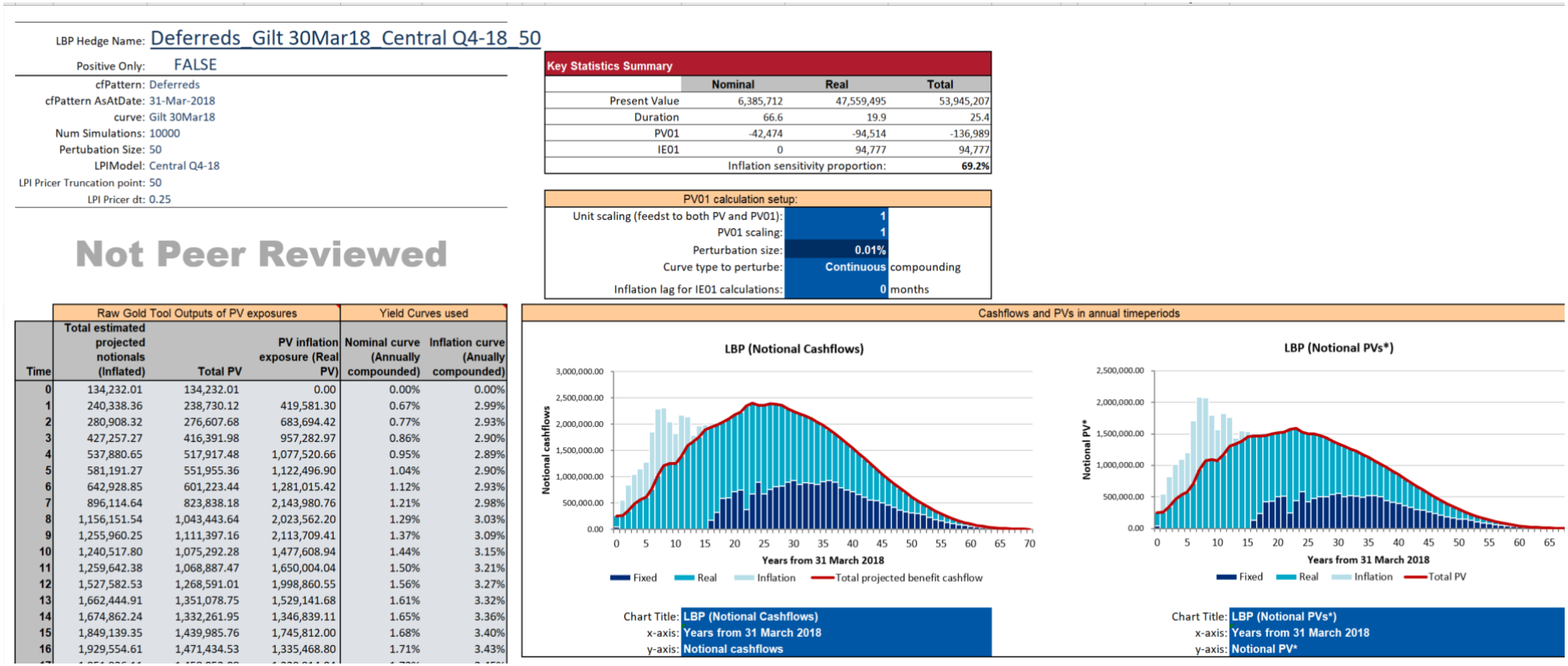


Figure 26: LPB Derivation Source: Author

Appendix 5: Output spreadsheet



LBP Hedge Name: Deferreds_Gilt 30Mar18_Central Q4-18_50
Positive Only: FALSE
cfPattern: Deferreds
cfPattern AsAtDate: 31-Mar-2018
curve: Gilt 30Mar18
Num Simulations: 10000
Pertubation Size: 50
LPIModel: Central Q4-18
LPI Pricer Truncation point: 50
LPI Pricer dt: 0.25

Not Peer Reviewed

Key Statistics Summary

	Nominal	Real	Total
Present Value	6,385,712	47,559,495	53,945,207
Duration	66.6	19.9	25.4
PV01	-42,474	-94,514	-136,989
IE01	0	94,777	94,777
Inflation sensitivity proportion:			69.2%

PV01 calculation setup:

Unit scaling (feedst to both PV and PV01):	1	
PV01 scaling:	1	
Perturbation size:	0.01%	
Curve type to perturbe:	Continuous	compounding
Inflation lag for IE01 calculations:	0	months

	Raw Gold Tool Outputs of PV exposures			Yield Curves used	
Time	Total estimated projected notionals (Inflated)	Total PV	PV inflation exposure (Real PV)	Nominal curve (Annually compounded)	Inflation curve (Anually compounded)
0	134,232.01	134,232.01	0.00	0.00%	0.00%
1	240,338.36	238,730.12	419,581.30	0.67%	2.99%
2	280,908.32	276,607.68	683,694.42	0.77%	2.93%
3	427,257.27	416,391.98	957,282.97	0.86%	2.90%
4	537,880.65	517,917.48	1,077,520.66	0.95%	2.89%
5	581,191.27	551,955.36	1,122,496.90	1.04%	2.90%
6	642,928.85	601,223.44	1,281,015.42	1.12%	2.93%
7	896,114.64	823,838.18	2,143,980.76	1.21%	2.98%
8	1,156,151.54	1,043,443.64	2,023,562.20	1.29%	3.03%
9	1,255,960.25	1,111,397.16	2,113,709.41	1.37%	3.09%
10	1,240,517.80	1,075,292.28	1,477,608.94	1.44%	3.15%
11	1,259,642.38	1,068,887.47	1,650,004.04	1.50%	3.21%
12	1,527,582.53	1,268,591.01	1,998,860.55	1.56%	3.27%
13	1,662,444.91	1,351,078.75	1,529,141.68	1.61%	3.32%
14	1,674,862.24	1,332,261.95	1,346,839.11	1.65%	3.36%
15	1,849,139.35	1,439,985.76	1,745,812.00	1.68%	3.40%
16	1,929,554.61	1,471,434.53	1,335,468.80	1.71%	3.43%

Cashflows and PVs in annual timeperiods

Chart Title: LBP (Notional Cashflows)
x-axis: Years from 31 March 2018
y-axis: Notional cashflows

Chart Title: LBP (Notional PVs*)
x-axis: Years from 31 March 2018
y-axis: Notional PV*

Figure 27: Output from Gold Tool part 1 Source: Author

RBT+ Priority:	MY benefits

Inflation Lag:	0	months

LBP cashflows for RBT+ & DDS

Tenor	Fixed CF	Real CF (un-inflated)
1	44,102	205,076
2	-298,540	528,739
3	-486,357	772,753
4	-571,456	942,861
5	-595,003	1,003,901
6	-668,533	1,080,447
7	-1,087,696	1,516,792
8	-1,274,362	1,817,991
9	-1,120,146	1,777,299
10	-810,230	1,518,783
11	-579,469	1,301,649
12	-789,557	1,493,885
13	-558,832	1,420,426
14	-121,089	1,138,375
15	-205,721	1,203,246
16	-111,373	1,178,243
17	170,088	1,005,463
18	323,015	909,706
19	594,748	763,975
20	608,770	763,317
21	724,248	713,233
22	761,328	697,006
23	376,158	899,769
24	675,109	766,471
25	905,221	623,959
26	676,993	699,343
27	759,199	655,723
28	817,849	610,976
29	828,439	579,904
30	902,704	515,907
31	937,063	470,845

LBP cashflows for LDI Manager

Start point of cashflow	End point of cashflow	Nominal Fixed Cashflows (£)	Inflation index start date	Inflation index end date	Real RPI Cashflow (Uninflated) (£)
31/03/2018	30/09/2018	134,232	31/03/2018	31/03/2018	0
30/09/2018	30/09/2019	-182,070	31/03/2018	31/03/2019	410,152
30/09/2019	30/09/2020	-413,416	31/03/2018	31/03/2020	655,314
30/09/2020	30/09/2021	-555,005	31/03/2018	31/03/2021	901,588
30/09/2021	30/09/2022	-581,173	31/03/2018	31/03/2022	998,576
30/09/2022	30/09/2023	-600,762	31/03/2018	31/03/2023	1,024,424
30/09/2023	30/09/2024	-726,947	31/03/2018	31/03/2024	1,151,705
30/09/2024	30/09/2025	-1,435,961	31/03/2018	31/03/2025	1,898,964
30/09/2025	30/09/2026	-1,085,986	31/03/2018	31/03/2026	1,765,461
30/09/2026	30/09/2027	-1,132,686	31/03/2018	31/03/2027	1,816,025
30/09/2027	30/09/2028	-464,135	31/03/2018	31/03/2028	1,249,774
30/09/2028	30/09/2029	-684,823	31/03/2018	31/03/2029	1,373,396
30/09/2029	30/09/2030	-879,359	31/03/2018	31/03/2030	1,636,711
30/09/2030	30/09/2031	-219,099	31/03/2018	31/03/2031	1,231,310
30/09/2031	30/09/2032	-18,326	31/03/2018	31/03/2032	1,066,215
30/09/2032	30/09/2033	-392,723	31/03/2018	31/03/2033	1,358,473
30/09/2033	30/09/2034	178,298	31/03/2018	31/03/2034	1,021,333
30/09/2034	30/09/2035	158,155	31/03/2018	31/03/2035	1,007,133
30/09/2035	30/09/2036	484,624	31/03/2018	31/03/2036	829,498
30/09/2036	30/09/2037	695,069	31/03/2018	31/03/2037	712,506
30/09/2037	30/09/2038	508,648	31/03/2018	31/03/2038	826,040
30/09/2038	30/09/2039	929,913	31/03/2018	31/03/2039	614,014
30/09/2039	30/09/2040	574,964	31/03/2018	31/03/2040	789,916
30/09/2040	30/09/2041	166,661	31/03/2018	31/03/2041	1,022,143
30/09/2041	30/09/2042	1,180,570	31/03/2018	31/03/2042	526,714
30/09/2042	30/09/2043	609,697	31/03/2018	31/03/2043	729,277
30/09/2043	30/09/2044	734,456	31/03/2018	31/03/2044	680,451
30/09/2044	30/09/2045	772,879	31/03/2018	31/03/2045	641,218
30/09/2045	30/09/2046	852,061	31/03/2018	31/03/2046	590,339
30/09/2046	30/09/2047	793,965	31/03/2018	31/03/2047	578,327
30/09/2047	30/09/2048	1,002,254	31/03/2018	31/03/2048	462,210
30/09/2048	30/09/2049	861,366	31/03/2018	31/03/2049	486,510

					Duration:	66.6	19.9	25.4	% Real
Totals	15,841,231	34,809,427	66,567,482	82,408,713		6,385,712	47,559,495	53,945,207	88.2%

Cashflow Profiles				Present Value Profiles			
Nominal CFs	Real CFs (un-inflated)	Real CFs (inflated)	Total CFs (inflated)	Nominal PVs	Real PVs	Total PVs	% Real
134,232.0	0.0	0.0	134,232.0	134,232.0	0.0	134,232.0	0.0%
-182,069.5	410,152.0	422,407.9	240,338.4	-180,851.2	419,581.3	238,730.1	175.8%
-413,416.0	655,313.5	694,324.4	280,908.3	-407,086.7	683,694.4	276,607.7	247.2%
-555,004.9	901,588.1	982,262.2	427,257.3	-540,891.0	957,283.0	416,392.0	229.9%
-581,173.1	998,575.5	1,119,053.8	537,880.7	-559,603.2	1,077,520.7	517,917.5	208.0%
-600,761.9	1,024,424.5	1,181,953.2	581,191.3	-570,541.5	1,122,496.9	551,955.4	203.4%
-726,947.5	1,151,705.4	1,369,876.3	642,928.8	-679,792.0	1,281,015.4	601,223.4	213.1%
-1,435,960.5	1,898,964.4	2,332,075.1	896,114.6	-1,320,142.6	2,143,980.8	823,838.2	260.2%
-1,085,986.4	1,765,461.3	2,242,137.9	1,156,151.5	-980,118.6	2,023,562.2	1,043,443.6	193.9%
-1,132,686.3	1,816,024.9	2,388,646.5	1,255,960.2	-1,002,312.2	2,113,709.4	1,111,397.2	190.2%
-464,135.2	1,249,773.6	1,704,653.0	1,240,517.8	-402,316.7	1,477,608.9	1,075,292.3	137.4%
-684,823.3	1,373,396.5	1,944,465.7	1,259,642.4	-581,116.6	1,650,004.0	1,068,887.5	154.4%
-879,359.1	1,636,711.0	2,406,941.6	1,527,582.5	-730,269.5	1,998,860.6	1,268,591.0	157.6%
-219,098.9	1,231,310.0	1,881,543.8	1,662,444.9	-178,062.9	1,529,141.7	1,351,078.7	113.2%
-18,325.8	1,066,215.3	1,693,188.0	1,674,862.2	-14,577.2	1,346,839.1	1,332,262.0	101.1%
-392,722.9	1,358,473.3	2,241,862.2	1,849,139.3	-305,826.2	1,745,812.0	1,439,985.8	121.2%
178,297.6	1,021,333.4	1,751,257.0	1,929,554.6	135,965.7	1,335,468.8	1,471,434.5	90.8%
158,154.8	1,007,133.1	1,793,781.3	1,951,936.1	118,138.0	1,339,914.0	1,458,052.1	91.9%
484,623.7	829,497.6	1,534,006.3	2,018,630.0	354,709.0	1,122,780.1	1,477,489.0	76.0%
695,068.6	712,505.5	1,367,472.1	2,062,540.8	498,651.9	981,043.6	1,479,695.5	66.3%
508,648.1	826,040.0	1,644,395.5	2,153,043.6	357,795.3	1,156,707.5	1,514,502.8	76.4%
929,912.8	614,013.7	1,267,031.0	2,196,943.8	641,591.3	874,185.2	1,515,776.5	57.7%
574,964.1	789,916.1	1,688,444.9	2,263,409.1	389,253.1	1,143,084.1	1,532,337.2	74.6%
166,661.0	1,022,142.7	2,261,302.0	2,427,963.0	110,770.4	1,502,962.5	1,613,732.9	93.1%
1,180,570.1	526,714.2	1,204,897.8	2,385,467.9	770,847.5	786,732.1	1,557,579.6	50.5%
609,696.9	729,277.2	1,723,196.7	2,332,893.6	391,409.8	1,106,248.4	1,497,658.2	73.9%
734,455.7	680,451.5	1,658,880.6	2,393,336.3	464,017.4	1,048,054.2	1,512,071.6	69.3%
772,879.0	641,218.5	1,610,990.3	2,383,869.3	481,045.9	1,002,692.9	1,483,738.8	67.6%
852,061.2	590,338.7	1,526,675.7	2,378,736.9	523,049.3	937,170.5	1,460,219.8	64.2%
793,964.8	578,326.6	1,537,731.2	2,331,696.0	481,256.4	932,085.5	1,413,341.9	65.9%
1,002,254.2	462,210.2	1,262,247.5	2,264,501.7	600,559.7	756,349.9	1,356,909.6	55.7%
861,365.9	486,510.4	1,363,269.8	2,224,635.7	510,784.3	808,410.0	1,319,194.3	61.3%

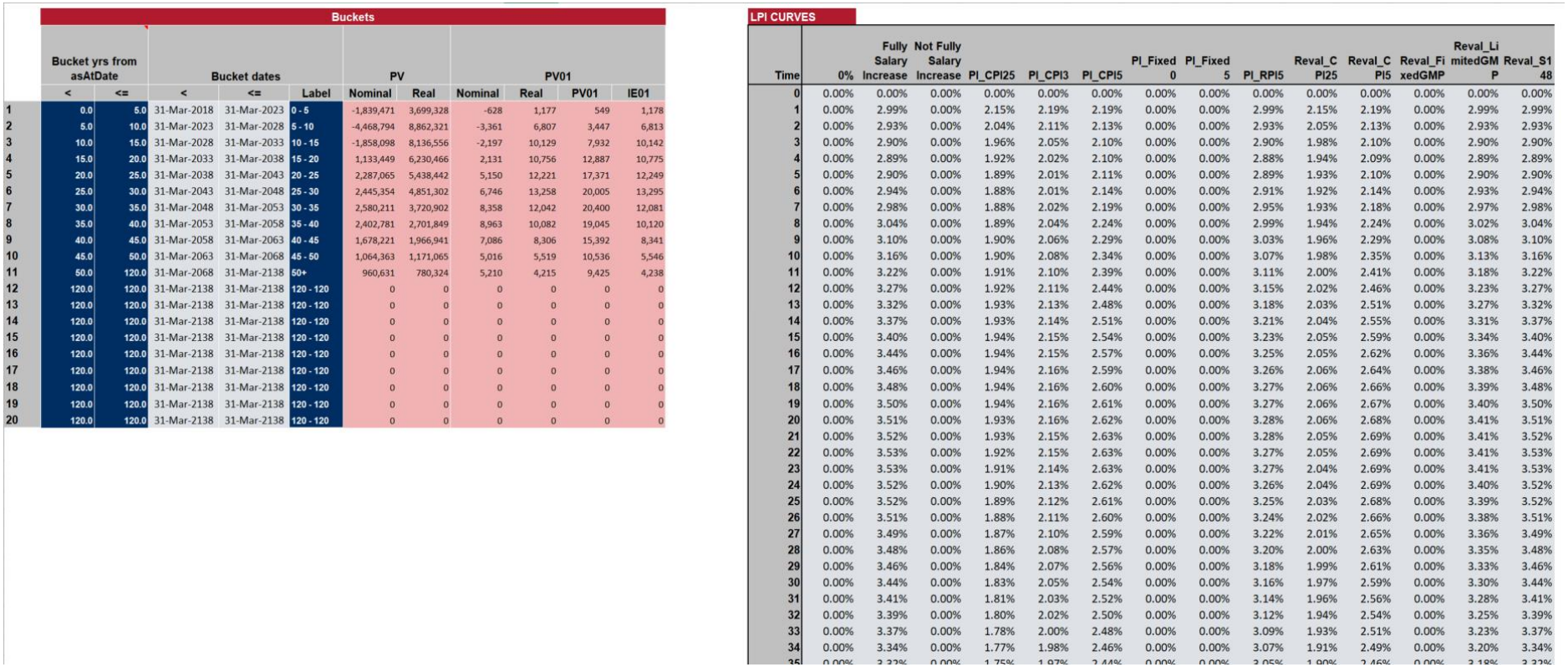
Figure 28: Output from Gold Tool part 2 Source: Author

Continuously compounded rate perturbations						Continuous:	TRUE	
- 42,474.48	- 94,514.05	-136,988.52	94,776.94	69.2%		- 136,988.52	94,776.94	69.2%

PV01s (in spot-space), Continuously compounded rate perturbation						PV01s (in forward-space)		
PV01 (Nominal)	PV01 (Real)	PV01 (total)	IE01	IE01 / DV01		forward DV01	forward IE01	IE01 / DV01
0.0	0.0	0.0	0.0	0.00%	0	0.0	0.0	0.00%
18.1	-42.0	-23.9	42.0	175.77%	5,381	-5,380.8	4,756.2	88.39%
81.4	-136.7	-55.3	136.8	247.22%	5,356	-5,356.4	4,714.7	88.02%
162.2	-287.1	-124.9	287.2	229.97%	5,328	-5,328.2	4,646.8	87.21%
223.8	-430.9	-207.1	431.1	208.13%	5,286	-5,286.1	4,551.5	86.10%
285.2	-561.1	-275.9	561.4	203.47%	5,234	-5,233.8	4,444.1	84.91%
407.8	-768.4	-360.6	768.8	213.20%	5,178	-5,178.1	4,332.3	83.67%
923.8	-1,500.3	-576.5	1,501.3	260.43%	5,117	-5,117.5	4,204.5	82.16%
783.8	-1,618.2	-834.4	1,619.5	194.09%	5,035	-5,034.7	3,990.4	79.26%
901.7	-1,901.5	-999.8	1,903.2	190.36%	4,930	-4,929.9	3,788.3	76.84%
402.1	-1,476.9	-1,074.8	1,478.3	137.55%	4,818	-4,818.4	3,577.1	74.24%
638.9	-1,814.0	-1,175.1	1,816.0	154.54%	4,710	-4,710.5	3,429.5	72.81%
875.8	-2,397.2	-1,521.4	2,400.1	157.75%	4,603	-4,603.2	3,264.7	70.92%
231.3	-1,986.6	-1,755.3	1,989.2	113.33%	4,476	-4,476.1	3,064.8	68.47%
20.4	-1,884.3	-1,863.9	1,886.9	101.24%	4,341	-4,340.7	2,912.0	67.09%
458.4	-2,616.8	-2,158.4	2,620.7	121.42%	4,207	-4,207.2	2,777.4	66.02%
-217.4	-2,135.0	-2,352.4	2,138.5	90.90%	4,063	-4,063.0	2,602.9	64.06%
-200.7	-2,275.9	-2,476.6	2,279.8	92.05%	3,916	-3,915.7	2,469.4	63.06%
-637.9	-2,019.2	-2,657.1	2,022.8	76.13%	3,770	-3,769.8	2,335.4	61.95%
-946.5	-1,862.2	-2,808.8	1,865.8	66.43%	3,622	-3,621.9	2,223.1	61.38%
-714.9	-2,311.1	-3,026.0	2,315.7	76.53%	3,474	-3,473.9	2,125.1	61.17%
-1,345.9	-1,833.9	-3,179.8	1,837.7	57.79%	3,322	-3,322.4	2,009.4	60.48%
-855.4	-2,512.0	-3,367.4	2,517.6	74.76%	3,171	-3,170.8	1,922.0	60.61%
-254.5	-3,452.8	-3,707.3	3,460.8	93.35%	3,018	-3,017.6	1,807.6	59.90%
-1,847.8	-1,885.9	-3,733.7	1,890.4	50.63%	2,856	-2,856.3	1,657.1	58.02%
-977.3	-2,762.2	-3,739.5	2,769.1	74.05%	2,701	-2,700.7	1,578.4	58.45%
-1,204.9	-2,721.4	-3,926.3	2,728.5	69.49%	2,551	-2,551.0	1,467.7	57.53%
-1,297.1	-2,703.6	-4,000.7	2,710.9	67.76%	2,400	-2,399.9	1,362.7	56.78%
-1,462.5	-2,620.4	-4,082.9	2,627.8	64.36%	2,252	-2,251.7	1,262.3	56.06%
-1,393.6	-2,699.1	-4,092.8	2,707.0	66.14%	2,106	-2,105.9	1,168.5	55.49%
-1,799.0	-2,265.6	-4,064.6	2,272.5	55.91%	1,965	-1,964.8	1,075.1	54.72%
-1,581.0	-2,502.2	-4,083.2	2,510.0	61.47%	1,829	-1,829.3	999.3	54.63%

Cashflows and PVs over the 12-month periods - FOR CHART ONLY													
Tenor	Period	Fixed benefit cashflow	Real (inflated) benefit cashflow	Fixed	Real	Inflation	Total projected benefit cashflow	Fixed PV	Real PV	Fixed	Real	Inflation	Total PV
0.5	0 - 1	43,197.26	211,203.93	43,197.26	211,203.93	0.00	254,401.19	43,806.43	209,790.65	43,806.43	209,790.65	0.00	253,597.08
1.5	1 - 2	-297,742.77	558,366.11	0.00	260,623.34	297,742.77	260,623.34	-293,968.96	551,637.86	0.00	257,668.90	293,968.96	257,668.90
2.5	2 - 3	-484,210.49	838,293.29	0.00	354,082.79	484,210.49	354,082.79	-473,988.86	820,488.69	0.00	346,499.83	473,988.86	346,499.83
3.5	3 - 4	-568,089.04	1,050,658.00	0.00	482,568.96	568,089.04	482,568.96	-550,247.09	1,017,401.81	0.00	467,154.73	550,247.09	467,154.73
4.5	4 - 5	-590,967.53	1,150,503.50	0.00	559,535.96	590,967.53	559,535.96	-565,072.36	1,100,008.78	0.00	534,936.42	565,072.36	534,936.42
5.5	5 - 6	-663,854.71	1,275,914.77	0.00	612,060.06	663,854.71	612,060.06	-625,166.76	1,201,756.16	0.00	576,589.40	625,166.76	576,589.40
6.5	6 - 7	-1,081,454.00	1,850,975.74	0.00	769,521.74	1,081,454.00	769,521.74	-999,967.28	1,712,498.09	0.00	712,530.81	999,967.28	712,530.81
7.5	7 - 8	-1,260,973.45	2,287,106.54	0.00	1,026,133.09	1,260,973.45	1,026,133.09	-1,150,130.57	2,083,771.48	0.00	933,640.91	1,150,130.57	933,640.91
8.5	8 - 9	-1,109,336.34	2,315,392.24	0.00	1,206,055.89	1,109,336.34	1,206,055.89	-991,215.41	2,068,635.80	0.00	1,077,420.40	991,215.41	1,077,420.40
9.5	9 - 10	-798,410.74	2,046,649.76	0.00	1,248,239.02	798,410.74	1,248,239.02	-702,314.46	1,795,659.17	0.00	1,093,344.72	702,314.46	1,093,344.72
10.5	10 - 11	-574,479.26	1,824,559.35	0.00	1,250,080.09	574,479.26	1,250,080.09	-491,716.62	1,563,806.49	0.00	1,072,089.87	491,716.62	1,072,089.87
11.5	11 - 12	-782,091.19	2,175,703.64	0.00	1,393,612.46	782,091.19	1,393,612.46	-655,693.06	1,824,432.30	0.00	1,168,739.24	655,693.06	1,168,739.24
12.5	12 - 13	-549,228.96	2,144,242.68	0.00	1,595,013.72	549,228.96	1,595,013.72	-454,166.23	1,764,001.12	0.00	1,309,834.88	454,166.23	1,309,834.88
13.5	13 - 14	-118,712.32	1,787,365.89	0.00	1,668,653.58	118,712.32	1,668,653.58	-96,320.04	1,437,990.39	0.00	1,341,670.35	96,320.04	1,341,670.35
14.5	14 - 15	-205,524.32	1,967,525.12	0.00	1,762,000.79	205,524.32	1,762,000.79	-160,201.70	1,546,325.56	0.00	1,386,123.86	160,201.70	1,386,123.86
15.5	15 - 16	-107,212.62	1,996,559.60	0.00	1,889,346.98	107,212.62	1,889,346.98	-84,930.26	1,540,640.40	0.00	1,455,710.14	84,930.26	1,455,710.14
16.5	16 - 17	168,226.21	1,772,519.15	168,226.21	1,772,519.15	0.00	1,940,745.36	127,051.89	1,337,691.42	127,051.89	1,337,691.42	0.00	1,464,743.31
17.5	17 - 18	321,389.24	1,663,893.80	321,389.24	1,663,893.80	0.00	1,985,283.04	236,423.52	1,231,347.04	236,423.52	1,231,347.04	0.00	1,467,770.56
18.5	18 - 19	589,846.16	1,450,739.21	589,846.16	1,450,739.21	0.00	2,040,585.37	426,680.46	1,051,911.82	426,680.46	1,051,911.82	0.00	1,478,592.27
19.5	19 - 20	601,858.34	1,505,933.83	601,858.34	1,505,933.83	0.00	2,107,792.17	428,223.62	1,068,875.53	428,223.62	1,068,875.53	0.00	1,497,099.14
20.5	20 - 21	719,280.44	1,455,713.26	719,280.44	1,455,713.26	0.00	2,174,993.70	499,693.29	1,015,446.33	499,693.29	1,015,446.33	0.00	1,515,139.61
21.5	21 - 22	752,438.48	1,477,737.96	752,438.48	1,477,737.96	0.00	2,230,176.45	515,422.16	1,008,634.64	515,422.16	1,008,634.64	0.00	1,524,056.81
22.5	22 - 23	370,812.57	1,974,873.44	370,812.57	1,974,873.44	0.00	2,345,686.01	250,011.71	1,323,023.31	250,011.71	1,323,023.31	0.00	1,573,035.02
23.5	23 - 24	673,615.55	1,733,099.88	673,615.55	1,733,099.88	0.00	2,406,715.43	440,808.92	1,144,847.32	440,808.92	1,144,847.32	0.00	1,585,656.24
24.5	24 - 25	895,133.49	1,464,047.26	895,133.49	1,464,047.26	0.00	2,359,180.75	581,128.66	946,490.24	581,128.66	946,490.24	0.00	1,527,618.90
25.5	25 - 26	672,076.29	1,691,038.66	672,076.29	1,691,038.66	0.00	2,363,114.96	427,713.60	1,077,151.28	427,713.60	1,077,151.28	0.00	1,504,864.89
26.5	26 - 27	753,667.36	1,634,935.45	753,667.36	1,634,935.45	0.00	2,388,602.81	472,531.64	1,025,373.57	472,531.64	1,025,373.57	0.00	1,497,905.20
27.5	27 - 28	812,470.12	1,568,832.98	812,470.12	1,568,832.98	0.00	2,381,303.10	502,047.62	969,931.71	502,047.62	969,931.71	0.00	1,471,979.33
28.5	28 - 29	823,013.02	1,532,203.44	823,013.02	1,532,203.44	0.00	2,355,216.46	502,152.88	934,627.98	502,152.88	934,627.98	0.00	1,436,780.86
29.5	29 - 30	898,109.52	1,399,989.35	898,109.52	1,399,989.35	0.00	2,298,098.87	540,908.06	844,217.71	540,908.06	844,217.71	0.00	1,385,125.76
30.5	30 - 31	931,810.08	1,312,758.65	931,810.08	1,312,758.65	0.00	2,244,568.73	555,671.99	782,379.97	555,671.99	782,379.97	0.00	1,338,051.96
31.5	31 - 32	852,456.78	1,352,568.55	852,456.78	1,352,568.55	0.00	2,205,025.33	503,142.99	798,312.84	503,142.99	798,312.84	0.00	1,301,455.83

Figure 29: Output from Gold Tool part 3 Source: Author



Buckets

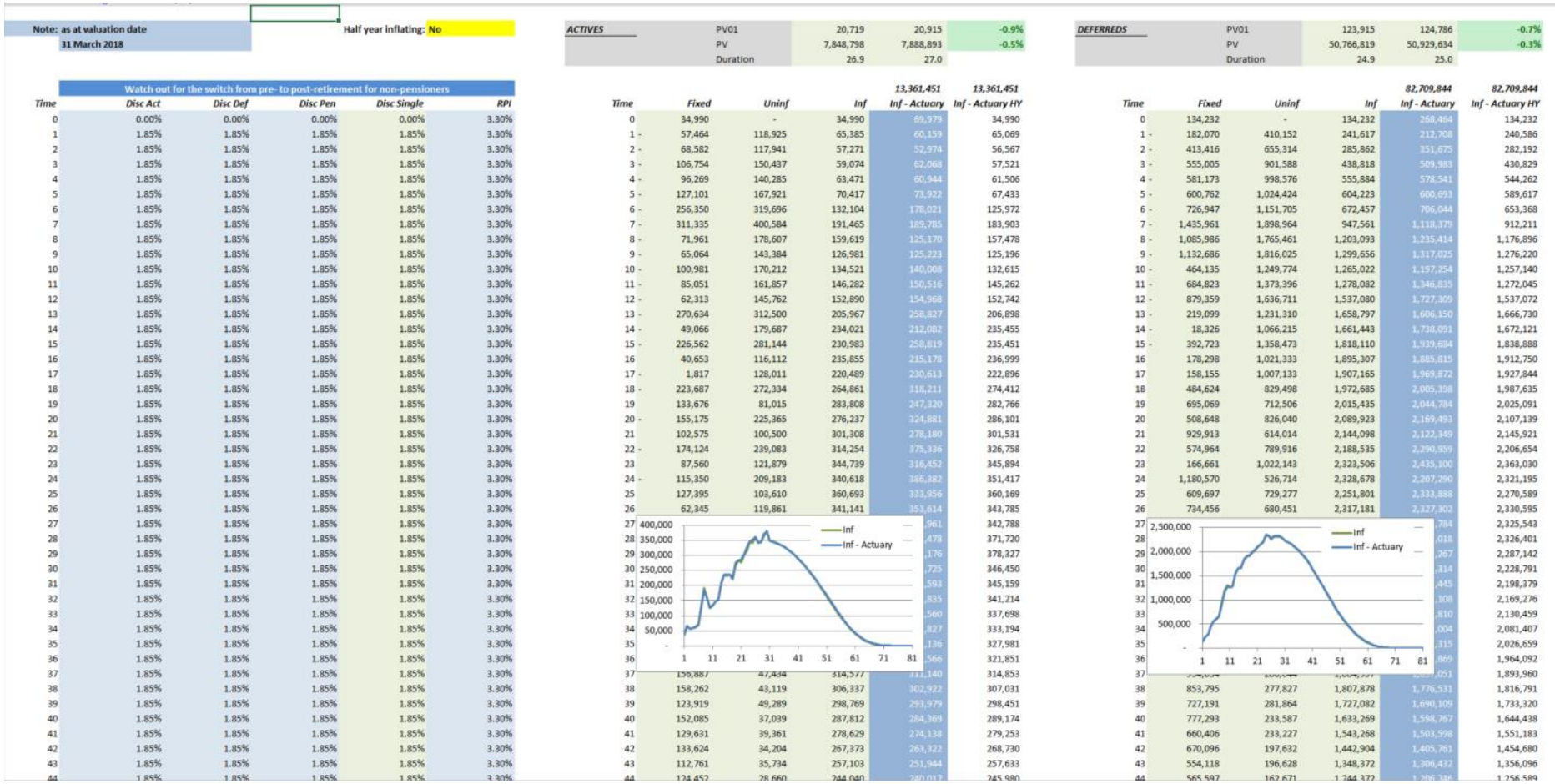
	Bucket yrs from asAtDate		Bucket dates			PV		PV01			
	<	<=	<	<=	Label	Nominal	Real	Nominal	Real	PV01	IE01
1	0.0	5.0	31-Mar-2018	31-Mar-2023	0 - 5	-1,839,471	3,699,328	-628	1,177	549	1,178
2	5.0	10.0	31-Mar-2023	31-Mar-2028	5 - 10	-4,468,794	8,862,321	-3,361	6,807	3,447	6,813
3	10.0	15.0	31-Mar-2028	31-Mar-2033	10 - 15	-1,858,098	8,136,556	-2,197	10,129	7,932	10,142
4	15.0	20.0	31-Mar-2033	31-Mar-2038	15 - 20	1,133,449	6,230,466	2,131	10,756	12,887	10,775
5	20.0	25.0	31-Mar-2038	31-Mar-2043	20 - 25	2,287,065	5,438,442	5,150	12,221	17,371	12,249
6	25.0	30.0	31-Mar-2043	31-Mar-2048	25 - 30	2,445,354	4,851,302	6,746	13,258	20,005	13,295
7	30.0	35.0	31-Mar-2048	31-Mar-2053	30 - 35	2,580,211	3,720,902	8,358	12,042	20,400	12,081
8	35.0	40.0	31-Mar-2053	31-Mar-2058	35 - 40	2,402,781	2,701,849	8,963	10,082	19,045	10,120
9	40.0	45.0	31-Mar-2058	31-Mar-2063	40 - 45	1,678,221	1,966,941	7,086	8,306	15,392	8,341
10	45.0	50.0	31-Mar-2063	31-Mar-2068	45 - 50	1,064,363	1,171,065	5,016	5,519	10,536	5,546
11	50.0	120.0	31-Mar-2068	31-Mar-2138	50+	960,631	780,324	5,210	4,215	9,425	4,238
12	120.0	120.0	31-Mar-2138	31-Mar-2138	120 - 120	0	0	0	0	0	0
13	120.0	120.0	31-Mar-2138	31-Mar-2138	120 - 120	0	0	0	0	0	0
14	120.0	120.0	31-Mar-2138	31-Mar-2138	120 - 120	0	0	0	0	0	0
15	120.0	120.0	31-Mar-2138	31-Mar-2138	120 - 120	0	0	0	0	0	0
16	120.0	120.0	31-Mar-2138	31-Mar-2138	120 - 120	0	0	0	0	0	0
17	120.0	120.0	31-Mar-2138	31-Mar-2138	120 - 120	0	0	0	0	0	0
18	120.0	120.0	31-Mar-2138	31-Mar-2138	120 - 120	0	0	0	0	0	0
19	120.0	120.0	31-Mar-2138	31-Mar-2138	120 - 120	0	0	0	0	0	0
20	120.0	120.0	31-Mar-2138	31-Mar-2138	120 - 120	0	0	0	0	0	0

LPI CURVES

Time	0%	Fully Salary Increase	Not Fully Salary Increase	PI_CPI25	PI_CPI3	PI_CPI5	PI_Fixed 0	PI_Fixed 5	PI_RPI5	Reval_CPI25	Reval_CPI5	Reval_FixedGMP	Reval_LimitedGMP	Reval_S148
0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1	0.00%	2.99%	0.00%	2.15%	2.19%	2.19%	0.00%	0.00%	2.99%	2.15%	2.19%	0.00%	2.99%	2.99%
2	0.00%	2.93%	0.00%	2.04%	2.11%	2.13%	0.00%	0.00%	2.93%	2.05%	2.13%	0.00%	2.93%	2.93%
3	0.00%	2.90%	0.00%	1.96%	2.05%	2.10%	0.00%	0.00%	2.90%	1.98%	2.10%	0.00%	2.90%	2.90%
4	0.00%	2.89%	0.00%	1.92%	2.02%	2.10%	0.00%	0.00%	2.88%	1.94%	2.09%	0.00%	2.89%	2.89%
5	0.00%	2.90%	0.00%	1.89%	2.01%	2.11%	0.00%	0.00%	2.89%	1.93%	2.10%	0.00%	2.90%	2.90%
6	0.00%	2.94%	0.00%	1.88%	2.01%	2.14%	0.00%	0.00%	2.91%	1.92%	2.14%	0.00%	2.93%	2.94%
7	0.00%	2.98%	0.00%	1.88%	2.02%	2.19%	0.00%	0.00%	2.95%	1.93%	2.18%	0.00%	2.97%	2.98%
8	0.00%	3.04%	0.00%	1.89%	2.04%	2.24%	0.00%	0.00%	2.99%	1.94%	2.24%	0.00%	3.02%	3.04%
9	0.00%	3.10%	0.00%	1.90%	2.06%	2.29%	0.00%	0.00%	3.03%	1.96%	2.29%	0.00%	3.08%	3.10%
10	0.00%	3.16%	0.00%	1.90%	2.08%	2.34%	0.00%	0.00%	3.07%	1.98%	2.35%	0.00%	3.13%	3.16%
11	0.00%	3.22%	0.00%	1.91%	2.10%	2.39%	0.00%	0.00%	3.11%	2.00%	2.41%	0.00%	3.18%	3.22%
12	0.00%	3.27%	0.00%	1.92%	2.11%	2.44%	0.00%	0.00%	3.15%	2.02%	2.46%	0.00%	3.23%	3.27%
13	0.00%	3.32%	0.00%	1.93%	2.13%	2.48%	0.00%	0.00%	3.18%	2.03%	2.51%	0.00%	3.27%	3.32%
14	0.00%	3.37%	0.00%	1.93%	2.14%	2.51%	0.00%	0.00%	3.21%	2.04%	2.55%	0.00%	3.31%	3.37%
15	0.00%	3.40%	0.00%	1.94%	2.15%	2.54%	0.00%	0.00%	3.23%	2.05%	2.59%	0.00%	3.34%	3.40%
16	0.00%	3.44%	0.00%	1.94%	2.15%	2.57%	0.00%	0.00%	3.25%	2.05%	2.62%	0.00%	3.36%	3.44%
17	0.00%	3.46%	0.00%	1.94%	2.16%	2.59%	0.00%	0.00%	3.26%	2.06%	2.64%	0.00%	3.38%	3.46%
18	0.00%	3.48%	0.00%	1.94%	2.16%	2.60%	0.00%	0.00%	3.27%	2.06%	2.66%	0.00%	3.39%	3.48%
19	0.00%	3.50%	0.00%	1.94%	2.16%	2.61%	0.00%	0.00%	3.27%	2.06%	2.67%	0.00%	3.40%	3.50%
20	0.00%	3.51%	0.00%	1.93%	2.16%	2.62%	0.00%	0.00%	3.28%	2.06%	2.68%	0.00%	3.41%	3.51%
21	0.00%	3.52%	0.00%	1.93%	2.15%	2.63%	0.00%	0.00%	3.28%	2.05%	2.69%	0.00%	3.41%	3.52%
22	0.00%	3.53%	0.00%	1.92%	2.15%	2.63%	0.00%	0.00%	3.27%	2.05%	2.69%	0.00%	3.41%	3.53%
23	0.00%	3.53%	0.00%	1.91%	2.14%	2.63%	0.00%	0.00%	3.27%	2.04%	2.69%	0.00%	3.41%	3.53%
24	0.00%	3.52%	0.00%	1.90%	2.13%	2.62%	0.00%	0.00%	3.26%	2.04%	2.69%	0.00%	3.40%	3.52%
25	0.00%	3.52%	0.00%	1.89%	2.12%	2.61%	0.00%	0.00%	3.25%	2.03%	2.68%	0.00%	3.39%	3.52%
26	0.00%	3.51%	0.00%	1.88%	2.11%	2.60%	0.00%	0.00%	3.24%	2.02%	2.66%	0.00%	3.38%	3.51%
27	0.00%	3.49%	0.00%	1.87%	2.10%	2.59%	0.00%	0.00%	3.22%	2.01%	2.65%	0.00%	3.36%	3.49%
28	0.00%	3.48%	0.00%	1.86%	2.08%	2.57%	0.00%	0.00%	3.20%	2.00%	2.63%	0.00%	3.35%	3.48%
29	0.00%	3.46%	0.00%	1.84%	2.07%	2.56%	0.00%	0.00%	3.18%	1.99%	2.61%	0.00%	3.33%	3.46%
30	0.00%	3.44%	0.00%	1.83%	2.05%	2.54%	0.00%	0.00%	3.16%	1.97%	2.59%	0.00%	3.30%	3.44%
31	0.00%	3.41%	0.00%	1.81%	2.03%	2.52%	0.00%	0.00%	3.14%	1.96%	2.56%	0.00%	3.28%	3.41%
32	0.00%	3.39%	0.00%	1.80%	2.02%	2.50%	0.00%	0.00%	3.12%	1.94%	2.54%	0.00%	3.25%	3.39%
33	0.00%	3.37%	0.00%	1.78%	2.00%	2.48%	0.00%	0.00%	3.09%	1.93%	2.51%	0.00%	3.23%	3.37%
34	0.00%	3.34%	0.00%	1.77%	1.98%	2.46%	0.00%	0.00%	3.07%	1.91%	2.49%	0.00%	3.20%	3.34%
35	0.00%	3.32%	0.00%	1.75%	1.97%	2.44%	0.00%	0.00%	3.05%	1.90%	2.46%	0.00%	3.18%	3.32%

Figure 30: Output from Gold Tool part 4 Source: Author

Appendix 6: Checker spreadsheet



Note: as at valuation date 31 March 2018

Half year inflating: No

Watch out for the switch from pre- to post-retirement for non-pensioners

Time	Disc Act	Disc Def	Disc Pen	Disc Single	RPI
0	0.00%	0.00%	0.00%	0.00%	3.30%
1	1.85%	1.85%	1.85%	1.85%	3.30%
2	1.85%	1.85%	1.85%	1.85%	3.30%
3	1.85%	1.85%	1.85%	1.85%	3.30%
4	1.85%	1.85%	1.85%	1.85%	3.30%
5	1.85%	1.85%	1.85%	1.85%	3.30%
6	1.85%	1.85%	1.85%	1.85%	3.30%
7	1.85%	1.85%	1.85%	1.85%	3.30%
8	1.85%	1.85%	1.85%	1.85%	3.30%
9	1.85%	1.85%	1.85%	1.85%	3.30%
10	1.85%	1.85%	1.85%	1.85%	3.30%
11	1.85%	1.85%	1.85%	1.85%	3.30%
12	1.85%	1.85%	1.85%	1.85%	3.30%
13	1.85%	1.85%	1.85%	1.85%	3.30%
14	1.85%	1.85%	1.85%	1.85%	3.30%
15	1.85%	1.85%	1.85%	1.85%	3.30%
16	1.85%	1.85%	1.85%	1.85%	3.30%
17	1.85%	1.85%	1.85%	1.85%	3.30%
18	1.85%	1.85%	1.85%	1.85%	3.30%
19	1.85%	1.85%	1.85%	1.85%	3.30%
20	1.85%	1.85%	1.85%	1.85%	3.30%
21	1.85%	1.85%	1.85%	1.85%	3.30%
22	1.85%	1.85%	1.85%	1.85%	3.30%
23	1.85%	1.85%	1.85%	1.85%	3.30%
24	1.85%	1.85%	1.85%	1.85%	3.30%
25	1.85%	1.85%	1.85%	1.85%	3.30%
26	1.85%	1.85%	1.85%	1.85%	3.30%
27	1.85%	1.85%	1.85%	1.85%	3.30%
28	1.85%	1.85%	1.85%	1.85%	3.30%
29	1.85%	1.85%	1.85%	1.85%	3.30%
30	1.85%	1.85%	1.85%	1.85%	3.30%
31	1.85%	1.85%	1.85%	1.85%	3.30%
32	1.85%	1.85%	1.85%	1.85%	3.30%
33	1.85%	1.85%	1.85%	1.85%	3.30%
34	1.85%	1.85%	1.85%	1.85%	3.30%
35	1.85%	1.85%	1.85%	1.85%	3.30%
36	1.85%	1.85%	1.85%	1.85%	3.30%
37	1.85%	1.85%	1.85%	1.85%	3.30%
38	1.85%	1.85%	1.85%	1.85%	3.30%
39	1.85%	1.85%	1.85%	1.85%	3.30%
40	1.85%	1.85%	1.85%	1.85%	3.30%
41	1.85%	1.85%	1.85%	1.85%	3.30%
42	1.85%	1.85%	1.85%	1.85%	3.30%
43	1.85%	1.85%	1.85%	1.85%	3.30%

ACTIVES				
	PV01	20,719	20,915	-0.9%
	PV	7,848,798	7,888,893	-0.5%
	Duration	26.9	27.0	

Time	Fixed	Uninf	Inf	13,361,451 Inf - Actuary	13,361,451 Inf - Actuary HY
0	34,990	-	34,990	69,979	34,990
1	57,464	118,925	65,385	60,159	65,069
2	68,582	117,941	57,271	52,974	56,567
3	106,754	150,437	59,074	62,068	57,521
4	96,269	140,285	63,471	60,944	61,506
5	127,101	167,921	70,417	73,922	67,433
6	256,350	319,696	132,104	178,021	125,972
7	311,335	400,584	191,465	189,785	183,903
8	71,961	178,607	159,619	125,170	157,478
9	65,064	143,384	126,981	125,223	125,196
10	100,981	170,212	134,521	140,008	132,615
11	85,051	161,857	146,282	150,516	145,262
12	62,313	145,762	152,890	154,968	152,742
13	270,634	312,500	205,967	258,827	206,898
14	49,066	179,687	234,021	212,082	235,455
15	226,562	281,144	230,983	258,819	235,451
16	40,653	116,112	235,855	215,178	236,999
17	1,817	128,011	220,489	230,613	222,896
18	223,687	272,334	264,861	318,211	274,412
19	133,676	81,015	283,808	247,320	282,766
20	155,175	225,365	276,237	324,881	286,101
21	102,575	100,500	301,308	278,180	301,531
22	174,124	239,083	314,254	375,336	326,758
23	87,560	121,879	344,739	316,452	345,894
24	115,350	209,183	340,618	386,382	351,417
25	127,395	103,610	360,693	333,956	360,169
26	62,345	119,861	341,141	353,814	343,785
27					342,788
28					371,720
29					378,327
30					346,450
31					345,159
32					341,214
33					337,698
34					333,194
35					327,981
36					321,851
37	156,887	47,434	314,577	311,140	314,853
38	158,262	43,119	306,337	302,922	307,031
39	123,919	49,289	298,769	293,979	298,451
40	152,085	37,039	287,812	284,369	289,174
41	129,631	39,361	278,629	274,138	279,253
42	133,624	34,204	267,373	263,322	268,730
43	112,761	35,734	257,103	251,944	257,633
44	124,452	28,660	244,040	239,017	245,980

DEFERREDS				
	PV01	123,915	124,786	-0.7%
	PV	50,766,819	50,929,634	-0.3%
	Duration	24.9	25.0	

Time	Fixed	Uninf	Inf	82,709,844 Inf - Actuary	82,709,844 Inf - Actuary HY
0	134,232	-	134,232	268,464	134,232
1	182,070	410,152	241,617	212,708	240,586
2	413,416	655,314	285,862	351,675	282,192
3	555,005	901,588	438,818	509,983	430,829
4	581,173	998,576	555,884	578,541	544,262
5	600,762	1,024,424	604,223	600,693	589,617
6	726,947	1,151,705	672,457	706,044	653,368
7	1,435,961	1,898,964	947,561	1,118,379	912,211
8	1,085,986	1,765,461	1,203,093	1,235,414	1,176,896
9	1,132,686	1,816,025	1,299,656	1,317,025	1,276,220
10	464,135	1,249,774	1,265,022	1,197,254	1,257,140
11	684,823	1,373,396	1,278,082	1,346,835	1,272,045
12	879,359	1,636,711	1,537,080	1,727,309	1,537,072
13	219,099	1,231,310	1,658,797	1,606,150	1,666,730
14	18,326	1,066,215	1,661,443	1,738,091	1,672,121
15	392,723	1,358,473	1,818,110	1,939,684	1,838,888
16	178,298	1,021,333	1,895,307	1,885,815	1,912,750
17	158,155	1,007,133	1,907,165	1,969,872	1,927,844
18	484,624	829,498	1,972,685	2,005,398	1,987,635
19	695,069	712,506	2,015,435	2,044,784	2,025,091
20	508,648	826,040	2,089,923	2,169,493	2,107,139
21	929,913	614,014	2,144,098	2,122,349	2,145,921
22	574,964	789,916	2,188,535	2,290,959	2,206,654
23	166,661	1,022,143	2,323,506	2,435,100	2,363,030
24	1,180,570	526,714	2,328,678	2,207,290	2,321,195
25	609,697	729,277	2,251,801	2,333,888	2,270,589
26	734,456	680,451	2,317,181	2,327,302	2,330,595
27					2,325,543
28					2,326,401
29					2,287,142
30					2,228,791
31					2,198,379
32					2,169,276
33					2,130,459
34					2,081,407
35					2,026,659
36					1,964,092
37					1,893,960
38	853,795	277,827	1,807,878	1,776,531	1,816,791
39	727,191	281,864	1,727,082	1,690,109	1,733,320
40	777,293	233,587	1,633,269	1,598,767	1,644,438
41	660,406	233,227	1,543,268	1,503,598	1,551,183
42	670,096	197,632	1,442,904	1,405,761	1,454,680
43	554,118	196,628	1,348,372	1,306,432	1,356,096
44	565,597	162,671	1,244,372	1,206,786	1,256,589

Figure 31: Comparison between cashflows from the Actuary and Gold Tool Source: Author

CURVES - from GoldTool at val date

Tenor	0%	Fully Salary Increase	Not Fully Salary Increase	PI_CPI25	PI_CPI3	PI_CPI5	PI_Fixed0	PI_Fixed5	PI_RPI5	Reval_CPI25	Reval_CPI5	Reval_Fixed GMP	Reval_LimitedGMP	Reval_S148
1	0.00%	2.99%	0.00%	2.15%	2.19%	2.19%	0.00%	0.00%	2.99%	2.15%	2.19%	0.00%	2.99%	2.99%
2	0.00%	2.93%	0.00%	2.04%	2.11%	2.13%	0.00%	0.00%	2.93%	2.05%	2.13%	0.00%	2.93%	2.93%
3	0.00%	2.90%	0.00%	1.96%	2.05%	2.10%	0.00%	0.00%	2.90%	1.98%	2.10%	0.00%	2.90%	2.90%
4	0.00%	2.89%	0.00%	1.92%	2.02%	2.10%	0.00%	0.00%	2.88%	1.94%	2.09%	0.00%	2.89%	2.89%
5	0.00%	2.90%	0.00%	1.89%	2.01%	2.11%	0.00%	0.00%	2.89%	1.93%	2.10%	0.00%	2.90%	2.90%
6	0.00%	2.94%	0.00%	1.88%	2.01%	2.14%	0.00%	0.00%	2.91%	1.92%	2.14%	0.00%	2.93%	2.94%
7	0.00%	2.98%	0.00%	1.88%	2.02%	2.19%	0.00%	0.00%	2.95%	1.93%	2.18%	0.00%	2.97%	2.98%
8	0.00%	3.04%	0.00%	1.89%	2.04%	2.24%	0.00%	0.00%	2.99%	1.94%	2.24%	0.00%	3.02%	3.04%
9	0.00%	3.10%	0.00%	1.90%	2.06%	2.29%	0.00%	0.00%	3.03%	1.96%	2.29%	0.00%	3.08%	3.10%
10	0.00%	3.16%	0.00%	1.90%	2.08%	2.34%	0.00%	0.00%	3.07%	1.98%	2.35%	0.00%	3.13%	3.16%
11	0.00%	3.22%	0.00%	1.91%	2.10%	2.39%	0.00%	0.00%	3.11%	2.00%	2.41%	0.00%	3.18%	3.22%
12	0.00%	3.27%	0.00%	1.92%	2.11%	2.44%	0.00%	0.00%	3.15%	2.02%	2.46%	0.00%	3.23%	3.27%
13	0.00%	3.32%	0.00%	1.93%	2.13%	2.48%	0.00%	0.00%	3.18%	2.03%	2.51%	0.00%	3.27%	3.32%
14	0.00%	3.37%	0.00%	1.93%	2.14%	2.51%	0.00%	0.00%	3.21%	2.04%	2.55%	0.00%	3.31%	3.37%
15	0.00%	3.40%	0.00%	1.94%	2.15%	2.54%	0.00%	0.00%	3.23%	2.05%	2.59%	0.00%	3.34%	3.40%
16	0.00%	3.44%	0.00%	1.94%	2.15%	2.57%	0.00%	0.00%	3.25%	2.05%	2.62%	0.00%	3.36%	3.44%
17	0.00%	3.46%	0.00%	1.94%	2.16%	2.59%	0.00%	0.00%	3.26%	2.06%	2.64%	0.00%	3.38%	3.46%
18	0.00%	3.48%	0.00%	1.94%	2.16%	2.60%	0.00%	0.00%	3.27%	2.06%	2.66%	0.00%	3.39%	3.48%
19	0.00%	3.50%	0.00%	1.94%	2.16%	2.61%	0.00%	0.00%	3.27%	2.06%	2.67%	0.00%	3.40%	3.50%
20	0.00%	3.51%	0.00%	1.93%	2.16%	2.62%	0.00%	0.00%	3.28%	2.06%	2.68%	0.00%	3.41%	3.51%
21	0.00%	3.52%	0.00%	1.93%	2.15%	2.63%	0.00%	0.00%	3.28%	2.05%	2.69%	0.00%	3.41%	3.52%
22	0.00%	3.53%	0.00%	1.92%	2.15%	2.63%	0.00%	0.00%	3.27%	2.05%	2.69%	0.00%	3.41%	3.53%
23	0.00%	3.53%	0.00%	1.91%	2.14%	2.63%	0.00%	0.00%	3.27%	2.04%	2.69%	0.00%	3.41%	3.53%
24	0.00%	3.52%	0.00%	1.90%	2.13%	2.62%	0.00%	0.00%	3.26%	2.04%	2.69%	0.00%	3.40%	3.52%
25	0.00%	3.52%	0.00%	1.89%	2.12%	2.61%	0.00%	0.00%	3.25%	2.03%	2.68%	0.00%	3.39%	3.52%
26	0.00%	3.51%	0.00%	1.88%	2.11%	2.60%	0.00%	0.00%	3.24%	2.02%	2.66%	0.00%	3.38%	3.51%
27	0.00%	3.49%	0.00%	1.87%	2.10%	2.59%	0.00%	0.00%	3.22%	2.01%	2.65%	0.00%	3.36%	3.49%
28	0.00%	3.48%	0.00%	1.86%	2.08%	2.57%	0.00%	0.00%	3.20%	2.00%	2.63%	0.00%	3.35%	3.48%
29	0.00%	3.46%	0.00%	1.84%	2.07%	2.56%	0.00%	0.00%	3.18%	1.99%	2.61%	0.00%	3.33%	3.46%
30	0.00%	3.44%	0.00%	1.83%	2.05%	2.54%	0.00%	0.00%	3.16%	1.97%	2.59%	0.00%	3.30%	3.44%
31	0.00%	3.41%	0.00%	1.81%	2.03%	2.52%	0.00%	0.00%	3.14%	1.96%	2.56%	0.00%	3.28%	3.41%
32	0.00%	3.39%	0.00%	1.80%	2.02%	2.50%	0.00%	0.00%	3.12%	1.94%	2.54%	0.00%	3.25%	3.39%
33	0.00%	3.37%	0.00%	1.78%	2.00%	2.48%	0.00%	0.00%	3.09%	1.93%	2.51%	0.00%	3.23%	3.37%
34	0.00%	3.34%	0.00%	1.77%	1.98%	2.46%	0.00%	0.00%	3.07%	1.91%	2.49%	0.00%	3.20%	3.34%
35	0.00%	3.32%	0.00%	1.75%	1.97%	2.44%	0.00%	0.00%	3.05%	1.90%	2.46%	0.00%	3.18%	3.32%
36	0.00%	3.30%	0.00%	1.74%	1.95%	2.42%	0.00%	0.00%	3.03%	1.88%	2.44%	0.00%	3.16%	3.30%
37	0.00%	3.28%	0.00%	1.73%	1.94%	2.40%	0.00%	0.00%	3.01%	1.87%	2.42%	0.00%	3.14%	3.28%
38	0.00%	3.27%	0.00%	1.72%	1.92%	2.39%	0.00%	0.00%	2.99%	1.86%	2.40%	0.00%	3.12%	3.27%
39	0.00%	3.25%	0.00%	1.71%	1.91%	2.38%	0.00%	0.00%	2.98%	1.84%	2.38%	0.00%	3.10%	3.25%
40	0.00%	3.24%	0.00%	1.70%	1.90%	2.36%	0.00%	0.00%	2.96%	1.83%	2.37%	0.00%	3.09%	3.24%
41	0.00%	3.23%	0.00%	1.69%	1.89%	2.35%	0.00%	0.00%	2.95%	1.82%	2.35%	0.00%	3.07%	3.23%
42	0.00%	3.22%	0.00%	1.68%	1.88%	2.34%	0.00%	0.00%	2.94%	1.81%	2.34%	0.00%	3.06%	3.22%
43	0.00%	3.21%	0.00%	1.67%	1.88%	2.34%	0.00%	0.00%	2.93%	1.81%	2.34%	0.00%	3.06%	3.21%
44	0.00%	3.21%	0.00%	1.67%	1.87%	2.33%	0.00%	0.00%	2.92%	1.80%	2.33%	0.00%	3.05%	3.21%
45	0.00%	3.21%	0.00%	1.66%	1.86%	2.33%	0.00%	0.00%	2.92%	1.80%	2.33%	0.00%	3.05%	3.21%
46	0.00%	3.21%	0.00%	1.66%	1.86%	2.33%	0.00%	0.00%	2.91%	1.79%	2.33%	0.00%	3.04%	3.21%
47	0.00%	3.22%	0.00%	1.65%	1.86%	2.33%	0.00%	0.00%	2.91%	1.79%	2.33%	0.00%	3.05%	3.22%

Active	Deferred	Pensioner	Total
65,014	240,338	1,721,459	2,026,811
56,380	280,908	1,699,244	2,036,532
57,145	427,257	1,676,449	2,160,851
60,941	537,881	1,654,010	2,252,832
66,641	581,191	1,632,267	2,280,100
123,907	642,929	1,612,073	2,378,909
180,613	896,115	1,592,675	2,669,403
154,870	1,156,152	1,573,390	2,884,411
123,531	1,255,960	1,553,878	2,933,369
131,184	1,240,518	1,533,520	2,905,221
144,108	1,259,642	1,511,671	2,915,422
152,044	1,527,583	1,487,844	3,167,470
206,892	1,662,445	1,461,474	3,330,811
236,283	1,674,862	1,431,960	3,343,105
237,405	1,849,139	1,398,789	3,485,333
239,748	1,929,555	1,361,412	3,530,715
226,179	1,951,936	1,319,368	3,497,484
279,945	2,018,630	1,272,357	3,570,933
289,164	2,062,541	1,220,180	3,571,885
293,458	2,153,044	1,162,838	3,609,340
309,958	2,196,944	1,100,549	3,607,451
336,916	2,263,409	1,033,780	3,634,105
357,195	2,427,963	963,184	3,748,342
363,172	2,385,468	889,695	3,638,335
372,214	2,332,894	814,356	3,519,464
354,555	2,393,336	738,371	3,486,262
352,861	2,383,869	662,929	3,399,659
382,315	2,378,737	589,244	3,350,296
388,141	2,331,696	518,407	3,238,244
353,410	2,264,502	451,430	3,069,341
350,651	2,224,636	389,093	2,964,380
345,025	2,185,415	331,946	2,862,386
339,814	2,136,043	280,358	2,756,215
333,602	2,076,404	234,463	2,644,469
326,732	2,011,481	194,191	2,532,405
319,006	1,939,332	159,291	2,417,629
310,518	1,860,476	129,403	2,300,397
301,346	1,775,721	104,088	2,181,154
291,575	1,685,942	82,858	2,060,374
281,305	1,592,228	65,224	1,938,757
270,583	1,495,589	50,714	1,816,885
259,452	1,397,134	38,894	1,695,480
247,933	1,297,914	29,371	1,575,218
236,046	1,199,002	21,798	1,456,847
223,795	1,101,356	15,870	1,341,020
211,225	1,005,930	11,317	1,228,472
198,344	913,301	7,889	1,119,535

		Single rates	Actuary	Estimate	Difference	Based on this we will...
Pre	0	0%	0.00%	0.00%	0.00%	Correctly estimate cashflow relating to these benefits
Pre	1	Fully Salary Increa	3.30%	3.32%	0.02%	Overestimate cashflow relating to these benefits
Pre	2	Not Fully Salary In	0.00%	0.00%	0.00%	Correctly estimate cashflow relating to these benefits
Post	3	PI_CPI25	1.80%	1.85%	0.05%	Overestimate cashflow relating to these benefits
Post	4	PI_CPI3	2.00%	2.05%	0.05%	Overestimate cashflow relating to these benefits
Post	5	PI_CPI5	2.45%	2.45%	0.00%	Underestimate cashflow relating to these benefits
Post	6	PI_Fixed0	0.00%	0.00%	0.00%	Correctly estimate cashflow relating to these benefits
Post	7	PI_Fixed5	0.00%	0.00%	0.00%	Correctly estimate cashflow relating to these benefits
Post	8	PI_RPI5	3.10%	3.11%	0.01%	Overestimate cashflow relating to these benefits
Pre	9	Reval_CPI25	2.50%	1.97%	-0.53%	Underestimate cashflow relating to these benefits
Pre	10	Reval_CPI5	2.50%	2.48%	-0.02%	Underestimate cashflow relating to these benefits
Pre	11	Reval_FixedGMP	0.00%	0.00%	0.00%	Correctly estimate cashflow relating to these benefits
Pre	12	Reval_LimitedGMI	3.30%	3.22%	-0.08%	Underestimate cashflow relating to these benefits
Pre	13	Reval_S148	3.30%	3.32%	0.02%	Overestimate cashflow relating to these benefits

Not Peer Reviewed

Figure 32: Comparing the LPI curves with the Actuary rates Source: Author

	Pre-retirement increase	Post-retirement increase	Commutation?	PV (Gilts Flat)	Pre-retirement PV %	Post-retirement PV %	Real % in deferment	Real % in payment	
Active	Fixed (0%)	Fixed (0%)	Y	14,375	0.2%	0.0%	0.0%	N/A	
	Fully Salary Increase	Fixed (0%)	Y	1,139,921	13.5%	0.0%	97.0%	N/A	
	Fully Salary Increase	PI_CPI25	N	4,262,084	50.6%	58.6%	97.0%	39.1%	
	Fully Salary Increase	PI_CPI5	N	2,899,332	34.4%	39.9%	97.0%	80.3%	
	Reval_S148	Fixed (0%)	N	7,988	0.1%	0.1%	97.0%	0.0%	
	Reval_S148	PI_CPI3	N	98,834	1.2%	1.4%	97.0%	51.1%	
	Total Active			**8,422,534**	**100.0%**	**100.0%**	**96.8%**	**55.7%**	OK
Deferred	Fixed (0%)	Fixed (0%)	N	283,021	0.5%	0.5%	0.0%	0.0%	
	Fixed (0%)	PI_CPI3	N	3,652,528	6.8%	6.8%	0.0%	51.8%	
	Reval_CPI25	Fixed (0%)	Y	131,652	0.2%	0.0%	42.1%	N/A	
	Reval_CPI25	PI_CPI25	N	939,274	1.7%	1.7%	42.1%	39.5%	
	Reval_CPI5	Fixed (0%)	N	12,965,531	24.1%	24.1%	92.7%	0.0%	
	Reval_CPI5	PI_CPI25	N	7,288,305	13.5%	13.6%	92.7%	39.5%	
	Reval_CPI5	PI_CPI5	N	26,924,918	50.0%	50.1%	92.7%	81.3%	
	Reval_LimitedGMP	Fixed (0%)	N	470,702	0.9%	0.9%	84.4%	0.0%	
	Reval_LimitedGMP	PI_CPI3	N	1,176,759	2.2%	2.2%	84.4%	51.8%	
	Total Deferred			**53,832,691**	**100.0%**	**100.0%**	**84.6%**	**51.5%**	OK
Pensioner		Fixed (0%)	N	15,095,739	45.8%	45.8%		0.0%	
		PI_CPI25	N	1,258,852	3.8%	3.8%		45.4%	
		PI_CPI3	N	4,681,166	14.2%	14.2%		62.3%	
		PI_CPI5	N	10,270,870	31.1%	31.1%		89.4%	
		PI_RPI5	N	1,509,996	4.6%	4.6%		84.4%	
	Reval_LimitedGMP	Fixed (0%)	N	33,276	0.1%	0.1%		0.0%	
	Reval_LimitedGMP	PI_CPI3	N	124,520	0.4%	0.4%		62.3%	
	Total Pensioner			**32,974,420**	**100.0%**	**100.0%**		**42.5%**	OK

Real % checks (gilts flat)

	Actuary TP	Estimated TP (Model PV)	PV (Gilts Flat)	PV % (Gilts Flat)	GoldTool PV	GoldTool PV %	Pre-ret Weight	Post-ret Weight	3DCF Real % (Gilts Flat)	Goldtool Real %	
Active	7,888,893	7,888,893	8,422,534	8.8%	8,446,190	8.9%	47.4%	52.6%	75.2%	72.4%	-2.8%
Deferred	50,929,634	50,929,634	53,832,691	56.5%	53,945,207	56.6%	47.4%	52.6%	67.2%	69.2%	2.0%
Pensioner	31,859,820	31,859,820	32,974,420	34.6%	32,975,059	34.6%	0.0%	100.0%	42.5%	43.2%	0.7%
Weighted Total	**90,678,347**	**90,678,347**	**95,229,646**	**100.0%**	**95,366,455**	**100.0%**			**63.1%**	**64.3%**	
Difference		**0.0%**			**0.1%**				Diff vs 3DCF:	1.2%	

Duration checks (gilts flat)

	PV	PV (%)	3DCF Duration	Goldtool Duration	
Active	8,422,534	8.8%	27.6	27.6	0.0
Deferred	53,832,691	56.5%	25.4	25.4	0.0
Pensioner	32,974,420	34.6%	12.3	12.3	0.0
Weighted Total	**95,229,646**	**100.0%**	**21.1**	**21.1**	
			Diff vs 3DCF:	**0.0**	

Sensitivity checks (gilts flat)

	PV01	IE01
Goldtool	200,926	129,212
3D Cashflows (calculation)	200,738	126,676
Difference	**0.1%**	2.0%

Figure 33: Main checks (compares several parameters) Source: Author

Cashflow-weighted single equivalent deltas

0%	Fully Salary Increase	Not Fully Salary Incr	PI_CPI25	PI_CPI3	PI_CPI5	PI_Fixed0	PI_Fixed5	PI_RPI5	Reval_CPI25	Reval_CPI5	Reval_FixedGMP	Reval_LimitedGMP	Reval_S148
0.0%	97.8%	0.0%	41.2%	54.8%	83.6%	0.0%	0.0%	78.0%	43.1%	93.6%	0.0%	85.9%	97.8%

Actives Cashflow-weighted single equivalent deltas

0%	Fully Salary Increase	Not Fully Salary Incr	PI_CPI25	PI_CPI3	PI_CPI5	PI_Fixed0	PI_Fixed5	PI_RPI5	Reval_CPI25	Reval_CPI5	Reval_FixedGMP	Reval_LimitedGMP	Reval_S148
0.0%	97.0%	0.0%	39.1%	51.1%	80.3%	0.0%	0.0%	74.7%	42.4%	92.2%	0.0%	84.0%	97.0%

Deferreds Cashflow-weighted single equivalent deltas

0%	Fully Salary Increase	Not Fully Salary Incr	PI_CPI25	PI_CPI3	PI_CPI5	PI_Fixed0	PI_Fixed5	PI_RPI5	Reval_CPI25	Reval_CPI5	Reval_FixedGMP	Reval_LimitedGMP	Reval_S148
0.0%	97.3%	0.0%	39.5%	51.8%	81.3%	0.0%	0.0%	75.5%	42.1%	92.7%	0.0%	84.4%	97.3%

Pensioners Cashflow-weighted single equivalent deltas

0%	Fully Salary Increase	Not Fully Salary Incr	PI_CPI25	PI_CPI3	PI_CPI5	PI_Fixed0	PI_Fixed5	PI_RPI5	Reval_CPI25	Reval_CPI5	Reval_FixedGMP	Reval_LimitedGMP	Reval_S148
0.0%	99.0%	0.0%	45.4%	62.3%	89.4%	0.0%	0.0%	84.4%	45.5%	96.0%	0.0%	89.8%	99.0%

Figure 34: Estimating the deltas to compare with Gold Tool Source: Author